EROSIVE TOOTH WEAR: PREVALENCE IN GERD PATIENTS AND EDUCATION IN US AND CANADIAN DENTAL SCHOOLS

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ABSTRACT

Caroline Nguyen Ngoc: Erosive Tooth Wear: Prevalence in GERD Patients and Education in US and Canadian Dental Schools
(Under the direction of Terry Donovan)

Specific aims were to determine the prevalence of erosive tooth wear (ETW) in gastroesophageal reflux disease (GERD) and control populations after controlling for other known risk factors (diet, medications, salivary flow rate and buffering capacity) and to survey US and Canadian dental schools regarding their teaching of ETW.

ETW was determined for subjects recruited (GERD/Control) using the Basic Erosive Wear Examination (BEWE) index. A survey was also sent to all US and Canadian dental education programs.

Results showed that prevalence of ETW in GERD subjects was 51.7% versus 18.2% for controls. ETW worsen with age and was the only co-factor investigated that significantly affected ETW. Although 100% of dental schools in the US and Canada taught dental erosion, only 15.3% of respondents could correctly identify clinical signs of dental erosion, showing that diagnosis of this condition remains unclear. Tooth wear index and diet counselling are also underutilized.

To my wonderful parents, Nguyen Ngoc Tan & Thi Thu Tran.

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LIST OF ABBREVIATIONS

ADA	American Dental Association
BEWE	Basic Erosive Wear Examination
CDA	California Dental Association
CE	Continuing Education
CEJ	Cemento-Enamel Junction
CODA	Commission on Dental Accreditation
CPAP	Continuous Positive Airway Pressure
DDS	Doctor of Dental Surgery
DE	Dental Erosion
DMD	Doctor of Medicine in Dentistry
EFCD	European Federation of Conservative Dentistry
ETW	Erosive Tooth Wear
GERD	Gastroesophageal Reflux Disease
GI	Gastrointestinal
IRB	Institutional Review Board
NC	North Carolina
OSA	Obstructive Sleep Apnea
PPI	Proton Pump Inhibitor
SOD	School of Dentistry
TW	Tooth Wear
TWI	Tooth Wear Index
UK	United Kingdom
UNC	University of North Carolina
US	United States
USA	United States of America
VEDE	Visual Erosion Dental Examination

WHO	World Health Organization

INTRODUCTION

Dental care providers are well-versed when it comes to prevention and management of dental caries. With deeper knowledge and efforts from the profession, and better awareness in the general population, caries rate continues to decrease. Since people are live longer and consequently keep their teeth longer, another notable problem arises in the form of non-carious tooth loss or tooth wear, that will surely require further preventive and restorative skills from the dental profession.[1, 2]

Definitions

Tooth wear can be defined as a chemical-mechanical cumulative loss of hard tooth structure unrelated to bacterial disease.[3, 4] This clinical observation may involve combinations of various etiologies, usually confluent and not mutually exclusive. These include attrition, abrasion, abfraction and erosion (table 1). In addition to accelerating other causes of tooth wear, acid is usually the main contributor and the term of choice to describe clinical manifestations should be erosive tooth wear (ETW) as it encompasses more accurately the multifactorial process involved (figure 1).[1] However, dental erosion (DE) and ETW is often used interchangeability in the literature. It has been suggested that DE should refer to surface loss caused exclusively by exposure to acid, whereas ETW should include both the erosive process and the effects of any mechanical abrasive forces.[5]

Prevalence

The prevalence of ETW is significant in general, both in primary and permanent teeth. Systematic reviews report that while a good amount of data exists on tooth wear in children and adolescent, studies are more scattered in adults because of the heterogeneity of the methodology used. However, there is a general consensus that the severity of ETW increases with age.[6, 7] This trend can be found in different parts of the world. In more recent studies, the prevalence of ETW found in Israel increased from 36.6% between the ages of 15-18 to 61.9% between the ages of 55-60.[2] Similarly, prevalence in Chinese adults was 67.5% among 35-49 year-olds and 100% among 50-74 year-olds.[8] The range of prevalence found in the literature is very wide. In adults (18-88 years-old), prevalence can vary as much as 4 to 100%.[9] Aside from the diverse methodologies used among existing studies making comparison difficult, major differences would be expected between countries solely based on cultural and environmental factors. A pan-European study including countries such as Estonia, Latvia, Finland, France, Italy, Spain and UK, found that an average of 29% of young adults (18-35 years old) had ETW with 3% showing severe signs of erosion. Differences between countries were significant.[10] It is interesting to note, however, that some authors have observed that the adoption of a more Westernized diet and lifestyle in Asia, is likely to have an effect on ETW in all age groups.[11] Numbers appear to be similar in an American and Japanese study where prevalence was 25% and 26.1%, respectively.[11, 12] A rise in prevalence and severity has also been observed especially in adolescents and young adults in many European countries and the USA.[2, 10, 13-15] It may be hypothesized that dietary habits have changed in recent years, and more importantly in those age groups, where higher frequency of consumption of newly marketed acidic foods and drinks may affect ETW.[16, 17] Because ETW is an irreversible cumulative process during a lifetime, prevalence is expected to increase in the future if acidic dietary trends continue in the same direction.

Erosive Process and Clinical Signs

When searching the literature, there seems to be a greater awareness of ETW in Europe compared to North America, where it is often dismissed as attrition and erroneously treated as such.[18] In fact, a recent survey of general practitioners in the US showed that only 30.5% could correctly identify all the clinical signs of dental erosion, although 86% felt competent to do so.[19] Because of the growing interest, the European Federation of Conservative Dentistry (EFCD) recently published a consensus report to help dental practitioners with diagnosis and management.[3] There are no specific diagnostic tools for ETW. Thus, diagnosis, prevention and management rely heavily on the dentist's ability to accurately identify clinical signs and relevant etiologies to assist in developing adequate management strategies.

Progression of ETW may be accelerated by erosion in combination with attrition, abrasion and abfraction. The erosive process begins with demineralization of hydroxyapatite or fluorapatite crystals in enamel, softening the outer surface. This initial stage is still somewhat reversible because of possible remineralization, but undetectable clinically making early diagnosis difficult.[20] Disorganized and defective apatite crystals are predisposed to further dissolution by non-bacterial acidic challenges and further attacks will eventually lead to permanent and clinically detectable loss of dental hard tissue. This process appears to progress at a much faster rate than caries as a surface lesion.[21] Dentin is even more susceptible to acid attacks than enamel because of its composition. Once the dentin is exposed, there is demineralization of apatite crystals at the interface between intertubular and peritubular dentin, and dentinal tubules may become significantly expanded.[22, 23] Collagen in exposed dentin is also vulnerable to attacks by the gastric enzymes pepsin and trypsin. Thus, clinical signs of rapid progression may be dentin hypersensitivity and absence of staining of the lesion. However, most patients do not present with symptoms, especially when progression is slow and reparative dentin has time

to obliterate tubules. Sometimes, even the most severe erosion cases leave the patients asymptomatic, emphasizing once again the importance of dental practitioner's awareness and early detection.[3, 24]

Early clinical signs of ETW is characterized by loss of enamel texture, a silky glossy appearance and sometimes a dulling of the surface gloss, referred to as the "whipped clay effect".[4, 25] Other characteristic signs include cupping of cusps on the occlusal surfaces and flattening of the occlusal structures. In later stages, occlusal morphology can completely disappear with hollowed out surfaces and restorations "standing proud" above adjacent tooth structures.[3, 4, 26-28] On smooth surfaces, convex areas flatten or concavities appear with the width usually exceeding the depth. Lesions are located coronal from the CEJ with an intact rim of enamel along the gingival margin, possibly due to plaque remnant acting as a diffusion barrier for acids or the neutralization effect of slightly alkaline sulcular fluid. Progression can result in pseudo-chamfers at the margin of the eroded surface.[29]

Initial enamel and dentin lesions are often difficult to differentiate from abrasive lesions.[4, 30] However, wedge-shaped defects from abrasion or abfraction usually have sharp margins coronally with cuts at right angles into the enamel surface, and the depth usually exceeds the width.[29] Abrasion is caused by an abnormal mechanical process, and aggressive oral hygiene habits (e.g. traumatic brushing or abrasive toothpaste) is most often at fault.[27, 31] It is also important to distinguish defects caused by attrition, where action of opposing teeth produces matching polished wear facets on the occlusal or incisal surfaces.[27] Lesions are typically flat, sharp bordered and glossy.[3, 29] However, thorough information gathering about medical and dental history is unequivocally necessary to confirm causative factors of clinical manifestations.

Etiology and Risk Factors

Acid that contributes to ETW can be of extrinsic or intrinsic origins, or a combination of both. Extrinsic acids are usually related to dietary habits, occupational hazards or acidic medications and other drugs, whereas intrinsic acids will involve rumination, vomiting or regurgitation that allow gastric acid to reach the oral cavity, such as in gastro-esophageal reflux disease (GERD), eating disorders and alcoholism.[32, 33] To assist clinicians identify the source of acid for proper management, locations of erosive lesions may be used as an indicator, but should not be the sole factor in determination.[34] Extrinsic erosion typically presents on labial surfaces of anterior teeth, buccal surfaces of posterior teeth and occlusal surfaces posterior mandibular teeth.[27] On the other hand, intrinsic erosion tends to occur on the anterior maxillary palatal surfaces, posterior maxillary and mandibular occlusal surfaces, and posterior mandibular buccal surfaces.[18, 27, 28, 31]

Much like dental caries, not everyone is at the same risk for ETW and various external and internal factors play an important role in susceptibility.[20]

External Factors

Dietary Habits

Dietary acids are largely responsible for ETW. The amount and more importantly the frequency of daily consumption of acidic foods and drinks increases risk significantly.[3] This applies particularly to teenagers and young adults who may regularly consume acidic beverages, like sports drinks, following intense physical exercise where dehydration and decrease in salivary flow may occur as well. Furthermore, the availability of heavily marketed flavored and energy drinks has been on the rise.[20, 28] In fact, a recent study of beverages in the United-States alone tested 379 beverages, 93% of which had a pH of less than 4.0.[16] The alarming increase in consumption of acidic soft drinks, fruit juices, fruit

drinks, sports drinks and carbonated beverages in general is even thought to be the leading cause of dental erosion observed among children and adolescents.[35, 36] However, the erosive potential of food, beverages and medicines should not be determined solely based on pH. Other factors must be taken into account, including buffering capacity, calcium, phosphate and fluoride concentrations, chelating properties, adherence to enamel, ability to stimulate salivary and temperature.[3, 21, 37] Another high risk group include populations on special diets, such as vegetarian or raw food diets, whose consumption of fruits can consist of up to 96% of their diet.[33, 38] It has been shown that consumption of citrus fruits more than twice daily increases ETW risk about 37 times compared to subjects who eat fruit less often.[39]

Occupational hazards

A few professional occupations put personnel at risk for ETW, such as workers in battery, galvanizing or plating factories, or in chemical, pharmaceutical or biotechnological labs or enterprises where they might be regularly exposed to acidic vapors without proper safety measures. Wine tasters are another group at risk for ETW as a result of swishing and swilling each mouthful of wine abundant in tartaric and malic acids for many seconds. Moreover, tasting sessions can last for hours, resulting in higher prevalence and severity of erosive lesions.[33, 40] Finally, competitive swimmers have also been reported to be susceptible to ETW, especially if the pH of the pool water is incorrectly monitored.[41, 42]

Medication and Other Drugs

Some medications (e.g. acidic saliva stimulants or acetylsalicylic acid) and food supplements (e.g. vitamin C) in chewable tablets, syrup or effervescent drinks are potentially erosive.[3, 33] Other medications, such as antihistamines, antiemetic and antiparkinson medicines can decrease salivary flow as a side effect, which can impact susceptibility to ETW.[20] On the other hand, other drugs, such as opiates, dopamine

antagonists and cancer chemotherapeutic agents can cause vomiting or emetic effects. Medications, such as aspirin and diuretics, can also irritate the stomach causing vomiting, which in return can cause dental erosion.[43, 44] Elderly populations are particularly affected since they usually are on multiple medications.[21, 28] Albuteral sulfate taken for asthma is acidic and significantly reduces salivary flow rates.

Internal Factors

Eating Disorders and GERD

Reported pH of gastric acids can be as low as 1 and can travel up to the oral cavity by vomiting (e.g. eating disorders) or regurgitation (e.g. GERD).[43] Populations at risk usually include young teens with anorexia or bulimia nervosa. These disorders are highly prevalent in females with body image issues, who self-induce vomiting.[28, 45] In contrast to vomiting, regurgitation is an involuntary condition that doesn't involve nausea, retching or abdominal contractions and is prevalent in GERD populations.[43, 46] GERD is defined as a condition which develops when the reflux of gastric content causes troublesome symptoms or complications, which includes possible repercussions in the oral cavity, especially when esophageal sphincters are weakened.[43, 47, 48] This chronic condition is usually diagnosed based on symptoms that motivate patients to consult their physicians, such as bitter or sour taste and burning sensation in the chest also known as heartburn, and is prevalent in about 10-20% of the general population.[33, 49] However, it has been reported that in 25% of confirmed GERD cases showing tooth erosions, condition is asymptomatic and may be left undiagnosed, which can lead to critical consequences including esophageal adenocarcinoma.[50, 51] Diagnosis of unexplained ETW by both dental and medical general practitioners are vital in these cases.

Saliva

Saliva is considered to be a biologic protective factor against ETW through[43, 52]

1) Formation of acquired pellicle that act as a semi-permanent membrane covering tooth surfaces
2) Dilution, clearance and neutralization of acid by mechanical cleansing (swallowing) or dependent on flow rate and buffering capacity
3) Prevention of demineralization by remineralization per its mineral content

Composition

Both saliva and teeth contain minerals such as calcium, phosphate and fluoride and ion exchange is possible.[43] Fluoride has been used in dentistry for many years because it has been shown that in high doses, fluoride has the ability to increase remineralization and prevent demineralization.[43] Calcium and phosphate are believed to also play similar roles, depending on their degree of saturation in teeth, saliva and ingested solutions.[1, 43, 53] In fact, classic concept of critical pH, taught for enamel and dentin of 5.2 and 6.7, respectively, concerns only dental caries as it refers to the average concentrations of minerals in plaque fluid.[1, 43, 54] Therefore, even if a solution has a pH below 5.2, it is possible that enamel erosion will not ensue.[20] The process of erosion is independent of plaque, this is why when it comes to erosion, a fixed critical pH does not exist and will vary depending on the concentration of calcium, phosphate and fluoride of the solution. Critical pH can be defined as the value at which a solution is saturated with respect to a specific solid, in this case, tooth minerals. At critical pH, there is an equilibrium where no dissolution or precipitation occur. Below critical pH however, fluid is under-saturated with tooth minerals and that's when dissolution of tooth surface can occur.[1, 20, 43, 52] After an acid attack, salivary calcium and phosphate may remineralize enamel in conjunction with fluoride ions, but the protective extend of saliva minerals is limited.[52]

Flow Rate

Flow rate is considered to be the best clinical indicator of protective properties of saliva since other salivary parameters, such as mineral content described above and amount of bicarbonate involved in buffering acids, are directly correlated to flow rate.[52] Swallowing also increases with increased flow rate, which permits dilution and clearance of acid more quickly.[43] Average unstimulated salivary flow rate is reported to be >0.3 mL/min with normal daily production between 0.5 and 1.5 L.[52, 55] If unstimulated and stimulated salivary flow reaches rates of 0.1 and 0.7 mL/min respectively, this is considered to be hyposalivation.[20, 55] Several activities, conditions and medications can decrease salivary flow resulting in hyposalivation or xerostomia, which puts populations concerned at higher risk for erosive damage. This includes most hypertension medications and antidepressants, dehydration from exercising, and reduction/loss of function of salivary glands from head and neck radiation in cancer therapy or Sjögren syndrome.[20, 43, 52] It has also been shown that patients taking more than 3 medications daily experience xerostomia, regardless if it is listed as side-effect or not.[19, 56]

Buffering capacity

The main buffering component of saliva is bicarbonate, which neutralizes acids in the mouth and shortens erosive episodes.[43] Its concentration in stimulated saliva is much more significant, and is about 12 times higher than in unstimulated saliva.[43, 57] Thus, stimulated saliva has high buffering capacity that plays an important function in protecting teeth from acidic challenges.[58] With good salivary flow rates, saliva can buffer acids with a pH of 3.5 to 6.1 in 30 seconds.[19, 21]

Acquired Pellicle

Acquired pellicle is a semi-permanent organic barrier devoid of bacteria that naturally coats tooth surfaces.[20, 59] It is formed by the adsorption of proteins, peptides, lipids and other macromolecules present in saliva, and provides protection since acid must diffuse through it to come into contact with teeth.[59] In addition to slowing down acid attacks, it also reduces calcium and phosphate release from enamel and dentin.[59] Composition and thickness varies between individuals and can be influenced by age and degeneration of salivary glands, which may influence its permeability.[19-21] It has been reported that patients with erosion appear to have less pellicle compared to a control population, while another study showed that its thickness varies within dental arches, with the thinnest found at the upper anterior palatal surface.[20, 60, 61]

Although saliva provides several protective properties, they are very limited when confronted with frequent and large amounts of strong acids over a long period of time, which can also easily displace acquired salivary pellicle.[43]

It is useful to take into consideration these external and internal factors when treating patients to determine, first of all, high risk populations and monitoring them accordingly. Secondly, when diagnosing patients with ETW, these factors can help providers better understand possible etiologies and therefore develop appropriate management strategies.

Preventive and Restorative Management

Prevention and early detection of ETW should be primary goals for practitioners, as severe stages of ETW can lead to aggressive and costly treatments.

A multidisciplinary approach should be considered, especially if etiology of ETW is determined to be intrinsic. For example, psychological counseling referrals should be made in eating disorders patients, and referrals to a primary care physician and gastroenterologist should be done in suspected GERD patients. If medications significantly affect the quality and quantity of saliva, discussions should take place with medical providers to assess different strategies to decrease risk, whether it be changing medications, dosage or frequency. To increase salivary flow, sugar free or xylitol mints and gums may also be used in addition to pilocarpine.[28] As for extrinsic sources, referral to a registered dietician may be recommended, but more importantly, a written diet diary should be prescribed to patients at risk for the dental team to analyze. Dietary counseling can then be personalized efficiently. It is suggested that two weekdays and a weekend be recorded to reflect as much as possible patient's dietary habits, according to which, diet modifications can be recommended.[19, 27, 28, 62] Frequent consumption of acidic foods and drinks, and some oral habits such as swishing or holding drinks in the mouth, may exacerbate erosive potentials.[28, 31, 37, 62, 63] Hence, behavioral management should also include the manner in which food is consumed (chewed, sucked, dissolved), eliminating certain foods or decreasing contact time (e.g. use of a straw).[19, 27, 64] The WATCH strategy was developed to offer straightforward understanding and advice regarding diet.[63] (Table 2) Products containing fluoride can also be used as adjuncts, such as fluoride varnish or prescription toothpastes.[3, 37] Ultimately, the objective of controlling risk factors is to stop progression of ETW, assuming that the patient is compliant.

Once etiologies have been identified and risk factors controlled, restorative management can be considered. Resin sealants or bonding agents can be applied over dentin when the erosive lesion does not compromise the existing tooth structure. This may reduce ETW progression and sensitivity for a limited time period.[3, 28] Restorations should be conservative and additive in nature, especially in mild and moderate lesions.[19, 28] In

advanced lesions, more aggressive therapies to restore esthetic and function may be indicated, especially if loss of vertical dimension has occurred due to severe loss of tooth structure.[65] Regular monitoring and evaluation of ETW management should be done during recall visits.[3]

Monitoring and Tooth Wear Indices

In order to monitor progression and management of ETW, photographs and diagnostic casts should be made periodically.[1, 25] To further raise awareness and aid practitioners in screening and monitoring progression and severity of ETW, wear indices have also been developed. These were designed to be used both in private practice and for research purposes.[66] Many research groups have developed their own tooth wear index, however, making research in this field challenging to compare. They are modified for each specific study according to study aims, and may vary in their manner of assessment, scale, choice of teeth, and other differing modalities.[2] In fact, World Health Organization (WHO) has stated that there is a need for more systematic population-based studies worldwide on the prevalence of dental erosion using a standard index of measurement.[67]

Many indices are largely based on the work by Eccles and Jenkins, which is a classification for assessment of dental erosion of non-industrial origin with three classes of lesions assigned to four tooth surfaces (table 3).[68] Smith and Knight later introduced the Tooth Wear Index (TWI), a comprehensive system where all four visible surfaces of all teeth are scored (table 4).[69] Although very reliable, this index was not suitable for use in day-to-day practice.[70] This index was then modified by Bardsley in 2004 to the Simplified Tooth Wear Index (table 5).[71] In addition to difficult study comparisons in meta-analyses, inter and intra-examiner reliability of many indices is an area of concern.[30] The accurate assessment by percentage of exposed dentin is often inconsistent between examiners.[72] A

workshop was conducted in Switzerland to discuss the various dental erosion indices available, and it was reiterated that a simple and standardized index is necessary. The workshop proposed the Basic Erosive Wear Examination (BEWE) be used for both the research field and dental clinicians.[30] In their opinion, and ideal index should be:

1. Easily applicable in general dental practice
2. Adaptable for epidemiological prevalence studies
3. Suitable for monitoring erosive lesion activities such as progression or arrestment of lesions
4. Easily reproducible under varying conditions for examination such as with/without magnification devices, ambient light, and hydration state of the tooth surface (dry/wet)
5. Capable of reflecting net exposure of an affected individual to the erosive challenge
6. Capable of indicating the need for treatment
7. Suitable for both children and adult, as well as permanent and primary teeth

BEWE, developed and recommended in 2008 by Bartlett et al., is a simple, reproducible and transferable scoring system for recording clinical findings and assisting in the decision-making process for the management of ETW.[66] A sextant based exam is conducted, where the surface of the tooth with the worst wear is graded in each sextant, resulting in a calculated cumulative score which allows risk and guidelines for management to be determined (table 6 and 7). A clinical study aiming to assess reliability of BEWE found it to be similar in distribution to TWI, and although it slightly underscored moderate to severe wear, the examination gave very few false positives, predicting severe wear with a sensitivity of 90.9% and a specificity of 91.5%.[70, 73] When comparing scores between 2 examiners, reliability showed moderate agreement and it was concluded by the authors that BEWE was an effective screening test for severe tooth wear, but because it is inherently

simple, scores should be interpreted with some caution.[73] Similarly, when BEWE was compared to another index, the visual erosion dental examination (VEDE) widely used in Norway where it originated, examiner reliability was acceptable for both, and highest agreement was found for sound and more severely affected surfaces involving dentin, while smallest agreement was found for initial and mild enamel lesions. However, no direct statistical comparison was made between both systems.[74] It can be argued that differentiation between enamel and dentin is an important factor for recording progression of ETW, hence, supporting the use of recent indices such as VEDE and the exact tooth wear index that distinguish these variables (table 8 and 9).[74, 75] However, these detailed scales not only impact the reproducibility of scores, but also may discourage its use in a clinical setting since it is not as easy and straightforward. To avoid diagnostic uncertainties, BEWE does not distinguish between enamel loss and exposed dentin.[66] A recent study further validated BEWE as a screening tool by showing that sextant cumulative score provided a good representation of tooth wear when compared to scores of all tooth surfaces.[76]

Although wear indices are still advocated, technology has expanded quickly in the field of 3D scanning. However, the absence of stable reproducible reference points make longitudinal assessment challenging.[77, 78] Current research in this area is promising, and further development is, without a doubt, warranted.

The purpose of this thesis was to add to the existing literature regarding prevalence of ETW, specifically in an American adult population and to assess education on the subject in U.S. and Canadian dental schools.

In part I, primary aim was to determine if subjects diagnosed with GERD had increased risk for ETW compared to a control population, therefore assessing prevalence of ETW in a GERD population. Secondary aim was to evaluate associations between ETW and

other potential risk factors, including age, sex, number of years since GERD diagnosis, diet, medication and quantity and quality of saliva.

In part 2, the aim was to investigate what is taught in dental schools regarding diagnosis, and both preventive and restorative management of dental erosion. Furthermore, respondents were asked about their impression of students' competence on the subject at the end of their training and the value of continuing education.

Table 1: Types of Tooth Wear[24, 79]

Type	Definition	Examples
Attrition	Physical wear as a result of the action of antagonistic teeth with no foreign substance intervening (two-body wear)	Bruxism
Abrasion	Physical wear as a result of mechanical processes involving foreign substances or objects (three-body wear)	Excessive forces used in tooth brushing, effect of abrasives in toothpaste, habits such as pen chewing, coarse or sandy food
Abfraction	Physical wear as a result of tensile or shear stress in the cemento-enamel region provoking microfractures in enamel and dentin (fatigue wear)	Tooth flexure
Extrinsic Erosion	Chemical wear as a result of extrinsic factors	Acidic diet (citrus fruits, fruit-based drinks, some carbonated drinks, herbal teas), occupational hazards (sommeliers, factory workers, competitive swimmers)
Intrinsic Erosion	Chemical wear as a result of endogenous acid	Regurgitated gastric juice: GERD, eating disorders

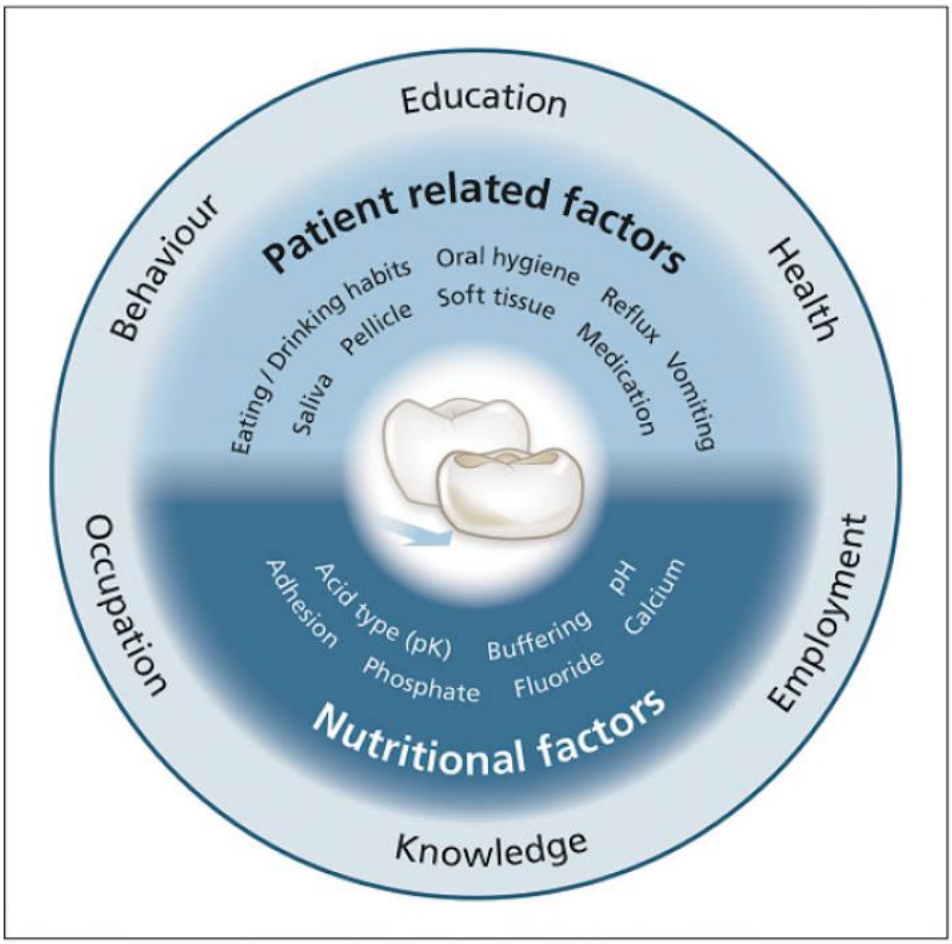

Figure 1: Interactions of the Different Factors for the Development of ETW[1]

Table 2: The Erosion WATCH Strategy for Diet Analysis and Advice for Patients with TW[63]

	Analysis	Advice
Water	Do you drink enough water?	Drink 1.5L of pure water/day. 2L, 2 hours before a game or 1L 1 hour before a game
Acids	Do you drink excess soft or sports drinks containing ascorbic, citric or phosphoric acid?	Avoid acid drinks when dehydrated in sports, work, or when drugs shut off salivary protection
Taste	Do you taste enough fresh fruit daily?	Eat a piece of fruit with every breakfast to stimulate saliva
Calcium	Are you getting enough calcium in your diet?	Milk, cheese and yogurt contain calcium and protect teeth against acids
Health	Do you have a healthy lifestyle and diet?	Healthy lifestyles can be dehydrating. Excess alcohol is dehydrating and causes gastric reflux
	Do you have a health problem?	Drugs, given for asthma, depression, hypertension, etc. shut off saliva

Table 3: Eccles Classification of Dental Erosion[68]

Class	Criteria
Class I	Superficial lesions - involving enamel only
Class II	Localized lesion – involving dentin < 1/3 of the surface
Class III	Generalized lesions – involving dentin >1/3 of the surface
a. Facial surfaces b. Lingual and palatal surfaces c. Incisal and occlusal surfaces d. Severe multisurface involvement	

Table 4: Smith and Knight Tooth Wear Index (TWI)[69]

Score	Surface	Criteria
0	B/L/O/I	No loss of enamel surface characteristics
	C	No change of contour
1	B/L/O/I	Loss of enamel surface characteristics
	C	Minimal loss of contour
2	B/L/O	Loss of enamel exposing dentin <1/3 of the surface
	I	Loss of enamel just exposing dentin
	C	Defect <1 mm deep
3	B/L/O	Loss of enamel exposing dentin >1/3 of the surface
	I	Loss of enamel and substantial loss of dentin, but not exposing pulp or secondary dentin
	C	Defect 1-2 mm deep
4	B/L/O	Complete loss of enamel, or pulp exposure, or exposure of secondary dentin
	I	Pulp exposure or exposure of secondary dentin
	C	Defect more than 2 mm deep, or pulp exposure, or exposure of secondary dentin

Table 5: Simplified Tooth Wear Index - Bardsley[71]

Score	Criteria
0	No wear into dentin
1	Dentin just visible (including cupping) or dentin exposed <1/3 of surface
2	Dentin exposure >1/3 of surface
3	Exposure of pulp or secondary dentin

Table 6: Basic Erosive Wera Examination (BEWE) - Criteria for Grading Erosive Wear[66]

Score	Criteria
0	No erosive tooth wear
1	Initial loss of surface texture
2	Distinct defect, hard tissue loss <50% of the surface area
3	Hard tissue loss ≥ 50% of the surface area

Table 7: Basic Erosive Wear Examination (BEWE) - Risk Levels as a Guide to Clinical Management[66]

Risk Level	Cumulative score of all sextants	Management
None	Less than or equal to 2	Routine maintenance and observation Repeat at 3-year intervals
Low	Between 3 and 8	Oral hygiene and dietary assessment, an advice, routine maintenance and observation Repeat at 2-year intervals
Medium	Between 9 and 13	Oral hygiene and dietary assessment, and advice, identify the main etiological factor(s) for tissue loss and develop strategies to eliminate respective impacts Consider fluoridation measures or other strategies to increase the resistance of tooth surfaces Ideally, avoid the placement of restorations and monitor erosive wear with study casts, photographs, or silicone impression Repeat at 6-12 months intervals
High	14 and over	Oral hygiene and dietary assessment, and advice, identify the main etiological factor(s) for tissue loss and develop strategies to eliminate respective impacts Consider fluoridation measures or other strategies to increase the resistance of tooth surfaces Ideally, avoid restorations and monitor tooth wear with study casts, photographs, or silicone impressions Especially in cases of severe progression consider special care that may involve restorations Repeat at 6-12 month intervals

Table 8: Visual Erosion Dental Examination (VEDE)[74]

Score	Definition
0	No erosion
1	Initial loss of enamel, no dentin exposed
2	Pronounced loss of enamel, no dentin exposed on the surface area
3	Exposure of dentin, <1/3 of the surface involved
4	1/2 - 2/3 of dentin exposed
5	>2/3 of dentin exposed, or pulp exposed

Table 9: The Exact Tooth Wear Index[75]

Exact Tooth Wear Index for Enamel	
0	No tooth wear: no loss of enamel characteristics or change in contour
1	Loss of enamel affecting <10% of the scored surface
2	Enamel loss affecting between 10% and 1/3 of the scored surface
3	Enamel loss affecting at least 1/3 but <2/3 of the scored surface
4	Enamel loss affecting 2/3 or more of the scored surface
Exact Tooth Wear Index for Dentin	
0	No dentinal tooth wear: no loss of dentin
1	Loss of dentin affecting <10% of the scored surface
2	Dentin loss affecting between 10% and 1/3 of the scored surface
3	Dentin loss affecting at least 1/3 but <2/3 of the scored surface
4	Dentin loss affecting 2/3 or more of the scored surface, no pulpal exposure
5	Exposure of secondary dentin formation or pulpal exposure

PART 1
PREVALENCE OF EROSIVE TOOTH WEAR IN GERD PATIENTS

Introduction

There had long been a need for general consensus over the blue-ribbon definition of gastro-esophageal reflux disease (GERD). Hence, the Montreal definition and classification of GERD was developed in 2006 and defines this disease as a condition which develops when the reflux of gastric content causes troublesome symptoms or complications.[47](figure 2) According to epidemiological studies, GERD is most prevalent in Western countries, including Europe and the US, where the weekly incidence of heartburn and/or acid regurgitation was reported to be between 10-20%.[49] This translates to about 15 millions of Americans experiencing daily heartburn symptoms.[19] It is much less prevalent, as low as <5%, in Middle-Eastern and Asian countries.[49, 80] The most common esophageal/typical symptoms encountered in GERD are heartburn and regurgitation but extra-esophageal/atypical symptoms can also be found, including dental erosion (DE), which is defined as the chemical dissolution of hard tooth tissue by acids not of bacterial origin.[4, 47, 80]

The association between GERD and DE can be noticed in two possible clinical situations[80, 81] :

1. Patients consulting physicians for GERD symptoms, who are then diagnosed with DE
2. Patients presenting to the dentist with DE, who are subsequently diagnosed with GERD

Only 42% of physicians strongly agree that GERD may cause dental erosion, while 35% agree with minor reservations and 19% with major reservations.[47, 51, 82] This suggests that perhaps dental consequences of GERD are poorly understood by physicians. In fact, a recent guide was published to help physicians recognize clinical features of GERD-related dental complications.[51] On the other hand, patients presenting at the dental office with unexplained erosive tooth wear (ETW) are often asymptomatic or at most oligosymptomatic in up to 25% of cases, and "silent GERD" should be suspected.[81, 83] A recent study by Wilder-Smith found that in subjects with severe ETW, few experienced frequent symptoms, but 69% actually had abnormal reflux when they were tested using both endoscopy and 24h multichannel intraluminal pH-impedance measurements.[81] Silent GERD is probably responsible for under-diagnosis of this condition, and if left undiagnosed can lead to critical consequences such as pre-malignant Barrett's esophagus or even esophageal adenocarcinoma.[50, 51, 84] In these cases, dentists just may be the first to suspect this potentially life-threatening condition and make appropriate referrals to a physician. Vice-versa, prompt referral to a dentist by physicians may save patients costly treatments before ETW causes extensive damage over time.[85] Thus, multidisciplinary approach is strongly encouraged.

The relationship between DE and GERD has been investigated in both children and adults. Systematic reviews have established a strong association, with a 24% prevalence of DE in GERD subjects and a 32.5% prevalence of GERD in DE subjects in an adult population.[80, 86, 87]. However, this association remains controversial, mainly because of the heterogeneity of methodology used not only to diagnose GERD (self-referral, symptom-based, endoscopy or 24h pH monitoring), but also for the measurement of DE (multiple tooth wear indices).[19, 88, 89] Theoretically, the acidity in the stomach may reach levels as low as pH 1, which if frequently in contact with teeth and for long periods of time will cause dental erosion. The exact mechanism of this phenomenon is still unclear because gastric

acids that have passed the lower esophageal sphincter may or may not progress into the mouth and this could partly explain why some experiencing daily GERD symptoms do not necessarily have ETW.[84, 90]

Although prevalence studies on erosion are beginning to emerge in the US, a vast majority of studies on prevalence of DE in an adult GERD population have been conducted outside of North America with varying results (table 10). The purpose of this study was to determine the prevalence of ETW in a GERD population compared to a control population in North Carolina, USA, and the association of ETW with other factors such as age, sex, medications, number of years since diagnosis, acidic diet, and salivary quality and quantity.

Materials and Method

Subject Selection

In this cross-sectional study approved by the University of North Carolina Biomedical Institutional Review Board (IRB, studies #11-2327 and #15-887), consecutive enrollment was performed at the Center for Esophageal Diseases and Swallowing Disorders, University of North Carolina Hospital Division of Gastroenterology and Hepatology for GERD subjects (group 1) and at the University of North Carolina, School of Dentistry (UNC-SOD) for control subjects (group 2) in 2012 and then between November 2015 and 2016. Inclusion criteria were as follows: adults (18-85 years old), at least 2 natural uncrowned teeth per sextant (total of 12 teeth), positive diagnosis of GERD or no history of GERD (control). Subjects unable to speak or understand English, with a history of anorexia or bulimia, or currently pregnant were excluded. GERD subjects were all recruited at UNC hospitals in gastroenterology specialty clinics, where they were referred and diagnosed with GERD by medical professionals through either troublesome heartburn/reflux symptoms, mucosal breaks at endoscopy and/or positive 24h pH monitoring by medical professionals. Based on

a pilot study where prevalence of medium to high ETW was 40% in GERD subjects and 15% in control subjects[19], a power analysis with α set at 0.05 and power of 0.8 indicated that a sample size of 98 subjects (n=49/group) was required to detect whether the difference between the proportions truly exists. Data from pilot study was combined to the present results for analysis.

Procedures

Subjects who agreed to participate signed an informed consent form and completed a health history questionnaire, which included demographics (sex and age), a list of their current medications and the number of years since their GERD diagnosis, when applicable. A one-time appointment only was required for subject participation, during which primary investigator (K.E. or C.N.N.) performed a dental examination to determine ETW, collected a stimulated salivary sample and provided a take-home 4-day diet diary to be completed and sent back for analysis.

Dental examination

Dental examination was carried out using 2x2 gauzes to dry teeth, a 25-mm diameter disposable plastic dental mirror (Sunstar Americas, Chicago, IL), and 3.25X magnification dental loupes and headlight (Orascoptic, Middleton, WI). Dental examination was done on subjects sitting upright on chairs in the medical office or dental operatory to standardize procedures in respective clinics. Clinical assessment of ETW was determined using Basic Erosive Wear Examination (BEWE)[66], which is a rapid and simple partial scoring system (0-3) that records the worst affected surface in each sextant (table 11). Teeth in each sextant were divided as follows: 1-5, 6-11, 12-16, 17-21, 22-27, 28-32. The cumulative score obtained categorized subject's severity of erosive wear (table 12).

Labial/buccal, lingual/palatal and occlusal surfaces were considered for examination. Crowned or missing teeth were systematically excluded.

Stimulated Salivary Sample

A salivary sample was collected by having subjects chew on a paraffin wax tablet and expectorate stimulated saliva in a sterile container for a total of 5 minutes using a stopwatch. Saliva samples were labelled and stored immediately on ice for transportation to the Oral Microbiology Lab at the UNC-SOD for analysis of flow rate and buffering capacity. Collection time was recorded thoroughly for each subject for flow rate calculations. As for buffering capacity, saliva was diluted four-fold in 0.0005N HCl and the final pH was recorded after ten minutes. Results were also categorized into risk levels (table 13). All samples were destroyed after testing.

Diet Diary Analysis

A labelled 4-day take home diet diary (Thursday-Sunday) was handed to each subject to be completed and returned in a pre-stamped addressed envelope. Verbal instructions were given, accompanied by written instructions and examples of how to complete the diet diary properly. This included recording of all food and drinks along with the quantity consumed to calculate more accurately the number of servings consumed for each acidic item. Acidic challenges were counted for each day and a daily average was calculated. Contact information obtained at the initial appointment aided in sending reminders and additional diet diary copies either through phone, mail and/or email messages. Upon reception of the diet diary, contact information was destroyed. Subjects who hadn’t returned their diet diaries received no more than 2 reminders during the remainder of the study period.

Statistical Analysis

Analysis was performed using SAS 9.4 software (SAS Institute, Cary, NC) with level of significance set at 0.05. Because of the cross-sectional nature of this study, descriptive statistics and bivariate calculations were first performed to evaluate heterogeneity between the 2 groups investigated, GERD and control, in terms of different co-factors. Four categories of BEWE scores were recorded: none, low, medium and high. However, from proportional distribution of previous results[19], it appears that difference between control and GERD groups occur in the medium risk level. Thus, "medium" and "high" categories were combined, as well as "none" and "low". Further analysis was then completed to assess if there was a difference between GERD and control groups in terms of ETW as defined by BEWE scores, followed by ETW association with covariates such as age, sex, number of medications, daily average frequency of acidic challenges from diet, salivary flow rate (mL/min) and salivary buffering capacity. An additional variable, number of years since GERD diagnosis (when applicable), was investigated for the latest data set (n=28 GERD subjects). Lastly, logistic regression analysis was used after adjusting for potential variables to assess true relationship between ETW and GERD as primary explanatory variable.

Results

2015-2016 Data Only

For this data set, sample size was 57 subjects (n=28 GERD and n=29 Control). Distribution between the 2 experimental groups did not statistically differ in terms of sex, age, daily acidic challenges, and saliva flow rate and buffering capacity ($p>0.05$). The control group consisted of 9 males and 20 females with a mean age of 46.2, and GERD group consisted of 8 males and 20 females with a mean age of 53.5. Six study participants failed to return their diet diary. Although higher proportions of GERD subjects compared to control subjects had compromised saliva flow rate and buffering capacity, this difference

was not statistically significant and the vast majority of participants had normal saliva flow rate and buffering capacity, 89.7% for controls and 71.4% for GERD subjects. In general, the GERD population took more daily medications than controls and this difference was statistically significant. Ninety-six percent (n=27) of GERD subjects took at least 1 medication per day with one third taking 6 of more medications every day versus 41.5% (n=12) in the control group taking no medication at all and 44.8% (n=13) between 1 and 3. BEWE combined categories (none-low and medium-high) were found to be significantly associated with GERD (p=0.0023), with prevalence of medium-high ETW of 64.3% (n=18) for GERD subjects versus 24.1% (n=7) for control subjects. (table 14)

Bi-variate analysis comparing combined categories of ETW revealed that 72% (n=18) of subjects with medium-high ETW were GERD subjects, compared to 28% (n=7) controls. Results also showed other co-factors that statistically significantly had an effect on erosive tooth wear severity, which included age, number of daily medications, daily acidic challenges from the diet and saliva buffering capacity. An additional factor, number of years since diagnosis and treatment, was investigated for this data set. The hypothesis was that GERD subjects that had been treated for a shorter period of time may have been exposed longer and more frequently to erosive gastric reflux, and consequently presenting with more severe ETW. Although number of years since diagnosis and treatment was slightly shorter for GERD subjects showing medium to high ETW, this difference was not statistically significant. (table 15) Finally, logistic regression was performed to truly assess factors associated with medium to high ETW after controlling for all variables. Analysis showed that only 3 factors were statistically significantly associated with ETW: GERD diagnosis, age and diet. (table 16)

Combined data

A total of 113 subjects were enrolled in this study (n=58 GERD and n=55 Control). Distribution of the 2 groups did not have any statistically significant differences in terms of sex, average daily acidic challenges, and saliva flow rate and buffering capacity ($p>0.05$). However, GERD participants were older than those in the control group ($p=0.021$). Subjects were mainly females for both groups: GERD group consisted of 19 males and 30 females and mean age was 53 years-old, control group on the other hand consisted of 22 males and 33 females and mean age was 47 years-old. Thirteen (11.5%) study participants failed to return their diet diary (9 GERD and 4 control subjects).1 subject failed to provide enough saliva for analysis and was categorized as high risk for both flow rate and buffering capacity. Although higher proportions of GERD subjects had intermediate to high risk in terms of saliva flow risk and buffering capacity, these were not statistically significant. Number of daily medications was not reported for 5 GERD subjects. GERD subjects had more daily medications in general than control subjects and this difference was statistically significant. (table 17)

The sample was mainly distributed between low (37 controls and 25 GERD) and medium (10 controls and 29 GERD) ETW categories. Sample distribution among remaining 12 subjects was 11 in the none ETW category, of which 8 were control subjects versus 3 GERD subjects, and finally 1 GERD subject in the high ETW category. (figure 3)

ETW, as represented by combined BEWE categories, was found to be significantly associated with GERD ($p=0.0002$). Of subjects having medium-high erosive tooth wear, 75% (n=30) were GERD subjects versus 25% (n=10) control subjects. (table 18) Consequently, higher prevalence of medium to high ETW was found in GERD subjects. Prevalence of medium to high ETW was 51.7% (n=30) for GERD subjects compared to 18.2% (n=10) for control subjects. Similarly, control subjects had higher prevalence of

none to low ETW compared to GERD subjects, with 81.1% (n=45) and 48.3% (n=28) respectively. Interestingly, within GERD subjects, distribution of none/low and medium/high ETW subjects was comparable (n=28 and n=30). (table 17) Further analysis was performed to assess if other covariates had an effect on ETW. Medium to high ETW was found in older subjects and in subjects with higher daily acidic challenges, and these differences were statistically significant ($p<0.05$). Highest proportion of none to low ETW was found in subjects with normal flow rate and buffering capacity, however, these results were not statistically significant. (table 18) Remaining variables revealed no statistical significance. When reversed logistic regression was performed to assess factors associated with medium to high ETW, analysis showed that only GERD diagnosis (OR: 0.28, 95% CI: 0.09, 0.81) and age (OR: 1.10, 95% CI: 1.05, 1.16) were significantly associated with ETW after controlling for other variables. (table 19)

Discussion

According to a systematic review, there is a strong association between GERD and ETW, although prevalence varied widely in an adult population with a range between 5-47.5%.[86] This association remains controversial however, with comparability between studies having been criticized mainly because of heterogeneity regarding methods used for GERD diagnosis and multiple tooth wear indices used for ETW evaluation (table 10). Furthermore, confounding factors were not always addressed.[88, 89] Results from the present study revealed that ETW was significantly associated with GERD (OR: 0.28, 95% CI: 0.09, 0.81). The GERD subjects included were properly diagnosed by gastroesophageal medical practitioners with diagnosis based on symptoms, endoscopy and 24h pH monitoring, the latter being the gold standard technique for the diagnosis of GERD. A validated and reproducible tooth wear index, BEWE, was also used for ETW assessment.[30, 66, 73, 76] Finally, data related to known factors affecting ETW were collected, such as dietary acidic

challenges, number of daily medications, and quantity and quality of saliva through salivary flow rates and buffering capacity.

Finally, all known factors susceptible to affect ETW was collected, such as acidic challenges from the diet, number of daily medications and saliva quantity and quality through stimulated salivary flow and buffering capacity.

Prevalence of medium to high ETW in a GERD population for combined data in this study was 51.7% and comparable to existing studies using similar methodology, whereas the control population had a prevalence of 18.2%. Other studies have found the prevalence of DE to be 61% and 48% for GERD participants compared to 28% and 13% in control participants in China and Spain, respectively.[91, 92] However, other studies have found no association between DE and GERD, with a 9% prevalence in Italy, 5% in Finland and 3.2% in Brazil.[93-95] ETW may have been underestimated for multiple reasons in the present study. First, air/water syringe and dental chairs were unavailable for optimal clinical examination and secondly, a significant number of potential GERD subjects were rejected due to insufficient teeth to be examined Teeth were either extracted or had full coverage restorations, suggesting that aggravation of ETW with time may have led to their loss or treatment among other reasons. Potential ETW of these teeth could not be assessed and prevalence of high ETW severity in GERD subjects may have been greater in reality than the results of the present study. In fact, only 1 high ETW subject was recorded and that subject was found in the GERD group (figure 3). Furthermore, control subjects may have been mislabeled as such, since they were not evaluated for silent GERD per endoscopy or 24h pH monitoring. Hence, we cannot assume that the totality of the control population investigated did not experience asymptomatic gastric reflux. If potential reflux episodes are frequent enough and reach the oral cavity, this condition may explain the medium ETW found in control subjects (n=10). It has been shown that there is a prevalent association between DE

and silent GERD, up to 25%, and these patients are probably asymptomatic because of higher than normal pain thresholds caused by chronic reflux and eventually become unresponsive to pain at all.[80, 81, 83]

Age was also significantly associated with ETW (OR: 1.10, 95% CI: 1.05, 1.16). This is to be expected since ETW is an irreversible process during a lifetime and would be expected to increase in severity with cumulative exposure to acids, whether it be extrinsic or intrinsic, as subjects get older.[6, 7] The prevalence of ETW in a general adult population found in the literature is very broad, ranging between 4%-100%.[9] In the present study, very few "none" subjects were found in both experimental groups, 11 subjects in total, with a mean age of 38.4 ±12.5 (figure 3). It has been reported that development of ETW in GERD takes 1-2 years of regular occurrence of acid exposure.[96, 97] This could explain the low prevalence of DE in GERD subjects in studies from Milani et al.[97] and and Jensdottir et al.[98], where the researched population was younger. Furthermore, PPI treatment chronically suppressing acid may act as a protective factor against ETW. Further research in this area is needed as dose and duration of medication needed for improvement is still unknown.[3] According to a randomized, double-blind control study by Wilder-Smith et al., there was a reduction in enamel loss after 3 weeks of acid suppression with PPI in GERD subjects with severe dental erosion.[99] In the present study, the number of years since diagnosis was investigated for a sub-population of GERD subjects (2015-2016 data only) treated with PPIs. Results showed that medium to severe ETW was found in subjects that had been treated with PPI for a shorter period of time, 9.1 (±9.6) years, compared to 12.8 (±8.9) years for subjects with none to low ETW, although this was not statistically significant given the small sample size (n=28). Similar proportions of GERD subjects were found to have none-low ETW (48.3%) and medium-high ETW (51.7%), but mechanisms behind ETW in GERD remain unclear. It has been proposed that acid reflux in some remains close to the lower esophageal sphincter and in others, the protective mechanism along the esophagus is

defective or overwhelmed and gastric acid reaches the upper esophageal sphincter and the oral cavity causing tooth erosion.[80] Moazzez et al. investigated acid reflux above the upper esophageal sphincter through 24h ambulatory pH monitoring at 4 sites along the esophagus and found it to be correlated with the severity of dental erosion, particularly on the palatal surfaces of incisors and this was significant during the night in a supine position.[100] Nocturnal reflux may play a major role in ETW severity since protective mechanisms during the day such as salivary flow, swallowing, gastric emptying and pressure of the upper esophageal sphincter are decreased during sleep.[84] In fact, it has been reported that obstructive sleep apnea (OSA) may predispose some patients to nocturnal GERD although this association is not fully understood.[101] There is even evidence supporting that treatment of OSA using continuous positive airway pressure (CPAP) improves nocturnal GERD symptoms in 75% of patients, even in those without OSA.[102] Hence, OSA might be an effect modifier of the relationship between GERD and ETW, but this was not investigated in the present study.

Since this was cross-sectional study and not a case-control study, some variables from the 2 experimental groups do not match. Bi-variate analysis showed that they were close in terms of sex, diet, salivary flow and buffering capacity, but statistically differed in age and number of medications. Although the GERD population was slightly older than the control population, logistic regression analysis still found a statistically significant difference in ETW between groups when controlling for age. As for medications, GERD subjects generally took more daily medications than controls, including PPI to treat their condition. It has also been shown that in addition to 63% of the most frequently prescribed medications in the US having the potential to cause xerostomia, patients taking more than 3 medications daily experience xerostomia, regardless if it is listed as side-effect or not.[56, 103] However, in the present study, the higher number of daily medications did not seem to affect their

salivary flow and buffering capacity, with a high proportion of subjects having normal saliva quantity and quality. Similar results were found in multiple studies for salivary flow rates.[53, 104, 105] However, Yoshikawa et al. found low salivary flow in GERD patients with ETW.[106] Stimulated saliva was collected in the present study because standardization is easier than in unstimulated salivary tests. Consumption of food and beverages and time of collection throughout the day may alter flow rate of unstimulated samples. It is interesting to note that although this was not statistically significant, there was a higher proportion of GERD subjects compared to control subjects having inferior salivary flow rates, 24% versus 11% respectively, and buffering capacity, 36% versus 27%, but whether this is related to their intake of medications or their GERD condition cannot be determined. This is supported by the findings in the UK and Finland, where lower median buffering capacity was found in GERD participants.[53, 107]

Daily acidic challenges from diet were low on average for both experimental groups and diet did not affect ETW severity in this study. Low acidic diet is to be expected in a diagnosed GERD population since some foods can trigger reflux episodes and diet modification is probably part of their treatment. Moreover, self-reported diets diaries are sometimes unreliable and difficult to analyze. On one hand, subjects may have omitted or inaccurately completed the forms since they were aware of the purpose of the study. On the other hand, time and method of consumption were not recorded and these are important risk factors affecting erosive potential.[3] For example, fruit juices have been shown to have very high erosive potential on its own.[17] However, sipping it throughout a morning for many hours causes more damage than drinking it quickly through a straw during a meal. Hence, a detailed in person interview is necessary to assess dietary habits more precisely. The erosive potential of food and beverages cannot rely solely on pH and other factors must be taken into account, including buffering capacity, calcium, phosphate and fluoride

concentrations, chelating properties, adherence to enamel, ability to stimulate salivary and temperature.[3, 21, 37]

Other important limitations include possible bias from the single examiner that recorded each data set since they were not blinded to the subject populations, and the small sample size (n=113). Hence, these results cannot be generalized and is only applicable to adults in the region studied in North Carolina, USA.

Conclusion

Within the limitations of this study, GERD was found to be significantly associated with medium to high ETW, with a prevalence of 51.7% and risk for ETW increased with age. Further multi-center studies are necessary to strengthen this association and possibly incorporate a longitudinal component to monitor ETW progression and impact of GERD treatment.

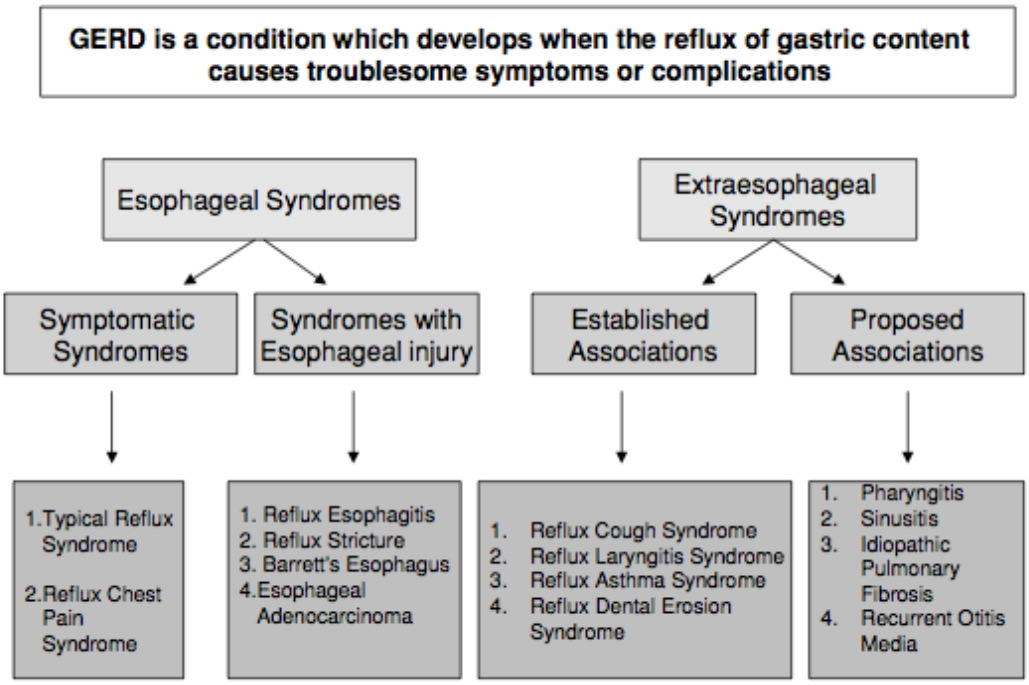

Figure 2: The Overall Definition of GERD and its Constituent Syndromes[47]

Table 10: Prevalence of ETW in Adults with GERD

Author (et al.) (year)	# of patients with GERD	GERD diagnostic method	Tooth wear index	Location	Prevalence (%)
Jarvinen[94] (1988)*	35	Endoscopy	Eccles and Jenkins	Finland	5
Meurman[53] (1994)*	117	Symptoms	Eccles and Jenkins	Finland	24
Schroeder[104] (1995)*	20/30	24h pH-metry	Eccles and Jenkins	USA	40
Loffeld[108] (1996)*	293	Endoscopy	N/A	Netherlands	32.5
Silva[95] (2001)	31	Symptoms, endoscopy and biopsy	Eccles and Jenkins	Brazil	3.2
Muñoz[92] (2003)*	181 129 78	Symptoms 24h pH-metry Endoscopy	Modified Eccles and Jenkins	Spain	47.5
Moazzez[107] (2004)*	18/31	24h dual pH-metry	Smith and Knight TWI	UK	Not stated
Jensdottir[98] (2004)	23	Symptoms, endoscopy and 24h ph-metry	Lussi modified TWI	Iceland	34.8
Oginni[109] (2005)*	125	Symptoms	Smith and Knight TWI	Nigeria	16
Benages[110] (2006)	181	Not reported	Eccles and Jenkins	Spain	47.5
Di Fede[93] (2008)	200	Symptoms, endoscopy and 24h ph-metry	Smith and Knight TWI	Italy	9

Wang[111] (2010)	88	Symptoms, endoscopy and 24h ph-metry	Smith and Knight TWI	China	48.9
Yoshikawa[106] (2012)	40	Symptoms and endoscopy	Modified Smith and Knight TWI	Japan	24.3
Correa[112] (2012)	30	Endoscopy, 24h dual pH-metry	Eccles and Jenkins	Brazil	Not stated
Tantbirojn[77] (2012)	12	Symptoms and physician dx	Quantitative analysis using optical scanner	USA	75
Yoshikawa[106] (2012)	40	Symptoms and endoscopy	Smith and Knight TWI	Japan	24.3
Preetha[113] (2013)	100	Endoscopy	Eccles and Jenkins	India	11
Picos[114] (2013)	60	Symptoms, endoscopy and 24h ph-metry	BEWE	Romania	35
Alavi[115] (2014)	31	Endoscopy	Not stated	Iran	22.6
Roesch-Ramos[116] (2014)	60	Symptoms, endoscopy and 24h ph-metry	Eccles and Jenkins	Mexico	78.9
Milani[97] (2016)	143	Symptoms	Smith and Knight TWI	Brazil	25.9
Li[91] (2017)	51	Symptoms and endoscopy	Smith and Knight TWI	China	60.8

*From Pace et al. (2008)[86]

Table 11: BEWE Criteria for Grading Erosive Wear

Score	
0	No erosive tooth wear
1	Initial loss of surface texture
2*	Distinct defect, hard tissue loss <50% of the surface area
3*	Hard tissue loss ≥ 50% of the surface area

*in scores 2 and 3 dentin is often involved

Table 12: BEWE Categories of ETW Severity

ETW Severity	Cumulative score of all sextants
None	Less than or equal to 2
Low	Between 3 and 8
Medium	Between 9 and 13
High	14 and over

Table 13: Salivary Risk Categories

	Normal	Intermediate Risk	High Risk
Flow Rate per Minute	1-2 mL	0.7 mL or less	0.1mL or less = Xerostomia
Buffering Capacity – pH	5.0-7.0	4.0-4.9	Below 4.0

Table 14: Demographics and Covariates for 2015-2016 Data

	Control (n=29) N (%)	GERD (n=28) N (%)	p value
Sex			0.893
Male	9.0 (31.0)	8.0 (28.6)	
Female	20.0 (69.0)	20 (71.4)	
Mean Age (±SD)	46.2 (±14.8)	53.5 (±14.2)	0.062
Medications			**0.0004***
0	12.0 (41.4)	1 (3.7)	
1-3	13.0 (44.8)	9 (32.1)	
4-5	3.0 (10.3)	9 (32.1)	
≥6	1.0 (3.5)	9 (32.1)	
BEWE			**0.0023***
None-Low	22 (75.9)	10 (35.7)	
Medium-High	7 (24.1)	18 (64.3)	
Mean Daily Acidic Challenges (±SD) (missing n=6)	3.1 (±1.2)	3.3 (±1.6)	0.679
Flow Rate Risk			0.081
Normal	26.0 (89.7)	20.0 (71.4)	
Intermediate-High	3.0 (10.3)	8.0 (28.6)	
Buffering Capacity			0.518
Normal	26.0 (89.7)	22.0 (78.6)	
Intermediate-High	3.0 (10.3)	6.0 (29.4)	

***p<0.05** statistically significant*

Table 15: Association of Covariates and ETW for 2015-2016 Data

	BEWE Category		p value
	None-Low N (%)	Medium-High N (%)	
Group			**0.0023***
Control	22.0 (68.8)	7.0 (28.0)	
GERD	10.0 (31.3)	18.0 (72.0)	
Sex			0.138
Male	7.0 (21.9)	10.0 (40.0)	
Female	25.0 (78.1)	15.0 (60.0)	
Mean Age (±SD)	42.6 (±12.1)	59.1 (±12.9)	**<0.0001***
Medications			**0.01***
0	9 (28.1)	4.0 (16.0)	
1-3	16 (50.0)	6.0 (24.0)	
4-5	5 (15.6)	7 (28.0)	
≥6	2 (6.3)	8 (32.0)	
Mean Daily Acidic Challenges (±SD) (missing n=6)	2.8 (±1.0)	3.8 (±1.6)	**0.012***
Flow Rate Risk			0.906
Normal	26.0 (81.3)	20.0 (80.0)	
Intermediate-High	6.0 (18.8)	5 (20.0)	
Buffering Capacity Risk			**0.011***
Normal	31.0 (96.9)	17.0 (68.0)	
Intermediate-High	1.0 (3.1)	8.0 (32.0)	
Mean number of Years Since Diagnosis (±SD) (GERD group only)	12.8 (±8.9)	9.1 (±9.6)	0.326

***p<0.05** statistically significant*

Table 16: Logistic Regression of Factors Associated with ETW for 2015-2016 Data

Factor	OR	95% C.I.	p value
Control vs GERD	0.085	0.010-0.739	0.026
Age	1.131	1.039-1.230	0.004
Daily acidic challenge	3.205	1.340-7.665	0.009

Table 17: Demographics and Covariates for Combined Data

	Control (n=55) N (%)	GERD (n=58) N (%)	p value
Sex			0.424
Male	22.0 (40.0)	19.0 (32.8)	
Female	33.0 (60.0)	39.0 (67.2)	
Mean Age (±SD) (missing n=3)	46.7 (±14.9)	52.9 (±13.4)	**0.021***
Medications (missing n=5)			**0.045***
0	23.0 (41.8)	6.0 (11.3)	
1-3	24.0 (43.6)	17.0 (32.0)	
4-5	6.0 (11.0)	11.0 (20.8)	
≥6	2.0 (3.6)	19.0 (35.9)	
BEWE			**0.0002***
None-Low	45.0 (81.8)	28.0 (48.3)	
Medium-High	10.0 (18.2)	30.0 (51.7)	
Mean Daily Acidic Challenges (±SD) (missing n=13)	3.6 (±1.3)	3.4 (±1.6)	0.387
Flow Rate Risk			0.06
Normal	49.0 (89.1)	44.0 (75.9)	
Intermediate-High	6.0 (10.9)	14.0 (24.1)	
Buffering Capacity			0.2
Normal	40.0 (72.7)	37.0 (63.8)	
Intermediate-High	15.0 (27.3)	21.0 (36.2)	

***p<0.05** statistically significant*

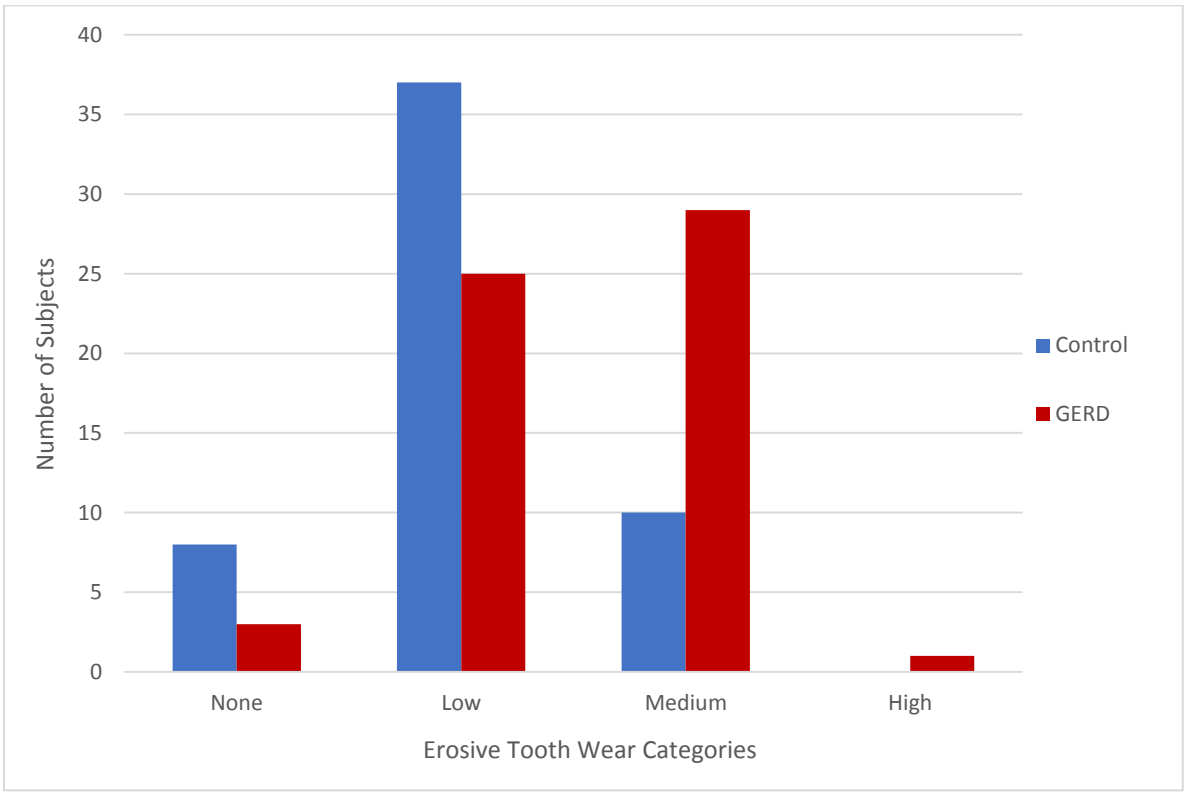

Figure 3: Sample Distribution of Combined Data

Table 18: Association of Covariates and ETW for Combined Data

	BEWE Category		p value
	None-Low N (%)	Medium-High N (%)	
Group			**0.0002***
Control	45.0 (61.6)	10.0 (25.0)	
GERD	28.0 (38.4)	30.0 (75.0)	
Sex			0.834
Male	27.0 (37.0)	14.0 (35.0)	
Female	46.0 (63.0)	26.0 (65.0)	
Mean Age (±SD) (missing n=3)	44.4 (±13.6)	59.6 (±10.3)	**<0.0001***
Medications (missing n=5)			0.100
0	23.0 (32.8)	6.0 (15.8)	
1-3	30.0 (42.9)	11.0 (28.9)	
4-5	7.0 (10.0)	10.0 (26.3)	
≥6	10.0 (14.3)	11.0 (29.0)	
Mean Daily Acidic Challenges (±SD) (missing n=13)	3.3 (±1.3)	4.0 (±1.6)	**0.022***
Flow Rate Risk			0.32
Normal	62.0 (84.9)	31.0 (77.5)	
Intermediate-High	11.0 (15.1)	9.0 (22.5)	
Buffering Capacity Risk			0.75
Normal	50.0 (68.5)	27.0 (67.5)	
Intermediate-High	23.0 (31.5)	13.0 (32.5)	

***p<0.05** *statistically significant*

Table 19: Logistic Regression of Factors Associated with ETW for Combined Data

Factor	OR	95% C.I.	p value
Control vs GERD	0.276	0.094 - 0.805	0.01084
Age	1.103	1.054 - 1.156	<0.0001

PART 2
EDUCATION OF DENTAL EROSION IN US AND CANADIAN DENTAL SCHOOLS

Introduction

There has been increased interest in dental erosion research in the past decade concomitant with the rise in prevalence and severity of this condition among the general population, especially in children, adolescents and young adults in many European countries and the USA.[2, 10, 13-15] Dental erosion (DE) is a multifactorial process resulting in irreversible loss of hard tooth structure due to extrinsic and intrinsic acids without bacterial involvement.[1] Because of its cumulative nature, both prevalence and severity is expected to increase with time. Hence, knowledge and awareness of this condition is important not only for dental practitioners, but also in the general population for proper prevention and management.

Diet is believed to be one of the major contributors of DE, especially in recent years with exponential availability of various acidic beverages and foods, and aggressive marketing efforts targeting children, teenagers and young adults.[20, 28, 117] Increased consumption of acidic beverages is thought to be the leading cause of DE observed in these age groups.[3, 35] Although public awareness is slowly increasing, DE and causative factors remain unclear to the general public. A Norwegian study among 18-year-olds revealed that weak or moderate awareness of acidic drinks was significantly associated with higher erosion risk and only 56% of participants with erosive lesions were aware of their condition.[118] Similarly, limited knowledge and awareness of DE has been reported in children in the UK, and adults in both China and Brazil usually confusing caries and

erosion.[119-121] Only 47% and 8.4% of participants could recall their dentists mentioning this condition in surveys conducted in Norway and the UK, respectively, showing a disconnect among dental professionals as well.[118, 119]

A literature review of dietary advice by dental practitioners found that no studies examining diet counselling specific to DE could be identified.[122] Very few dentists and hygienists in the US provided this service, and dietary advice is most often brief and unspecific.[19, 122, 123] Unfortunately, very little financial incentive exists for dental practitioners in terms of preventive and conservative management of DE. Insufficient and inconsistent training may be at fault as well.[64, 122] This is supported by many surveys investigating knowledge and management of DE among dental faculty, general practitioners, and prosthodontists in various countries around the world.[19, 119, 121, 124-126] However, greater awareness of DE is consistent in Western European countries such as the UK and Norway, compared to North America.[18, 19, 125, 126] A recent survey of US general practitioners revealed that although a vast majority felt competent diagnosing DE, discussing etiology with their patients and treating such cases, only 30.5% could correctly identify all the clinical signs.[19]

It has been noted that diagnosis and etiology are attributed differently between countries around the world, with Europe attributing tooth wear mainly to erosion, compared to attrition and abrasion in the USA, suggesting that the US dental education system is not imparting a good understanding of erosive tooth wear.[18, 19] Furthermore, in an issue dedicated entirely to erosion by the California Dental Association (CDA), it has been suggested that early diagnosis and management of DE can be challenging because it is not emphasized in dental curricula and is not a desirable continuing education topic.[64] When a Brazilian school was surveyed, they found that the understanding of DE was not good among their students and faculty, with 61.5% of students not feeling prepared to diagnosed the condition.[121] However, encouraging results was found in a recent Yemeni study

investigating awareness among general practitioners and dental students in their final year. Although much more education is still warranted since about only half the respondents showed in-depth knowledge, younger respondents were more likely to identify the commonly known causative factors, use tooth wear index and give preventive advice to their patients, indicating that perhaps current dental education has improved in this regard.[124]

The purpose of this study was to assess education on DE in US and Canadian dental schools regarding diagnosis, preventive and restorative management, including diet analysis, faculty's impression of students' competence at the end of their training and the value of continuing education.

Materials and Methods

Survey development

A 17-question survey was developed using a web-based survey tool, Qualtrics Software (Qualtrics, Provo, Utah). Questions included respondents' demographics, inclusion of DE in the curriculum, time devoted to the topic and department(s) involved. Questions addressing clinical signs, etiologic factors, preventive measures, advocated treatments and tooth wear indices followed. Assessment of diet analysis education was also investigated, and finally, respondents' opinion on the students' competency at the end of their training and the merit of continuing education on the subject was surveyed.

Sample and Survey Distribution

A recipient list was created using Microsoft Excel (Microsoft, inc.). Contact information was obtained by searching public websites of all US and Canadian CODA-accredited predoctoral (DDS/DMD) dental education programs (n=76). This included names,

titles, schools and email addresses of deans, associate dean for academic affairs (or equivalent) and selected faculty in restorative/cariology (or equivalent) and oral medicine/pathology (or equivalent) departments. Personalized email-invitations were generated by linking recipient list to the mail merge option in Microsoft Word (Microsoft, Inc.), and sent through the primary investigator's UNC email account. Anonymous survey-link redirecting respondents to the Qualtrics survey was provided. Recipients were asked to respond and/or forward the link to the appropriate person in their respective school. Survey distribution and response collection were conducted between August 2016 and October 2016. After initial invitation, reminder emails were sent to contacts of unresponsive schools every 2-3 weeks, for up to 4 attempts. Completion of the survey served as implied consent per University of North Carolina-Chapel Hill IRB-exemption #16-0611.

Statistical Analysis

Several responses from a single school were collapsed for analysis as one response using Microsoft Excel (Microsoft, Inc.). Analysis was performed using SAS 9.4 software (SAS Institute, Cary, NC). Frequencies and percentages were calculated for each survey question and weighted values were assigned to clinical signs of DE to determine how accurately these were taught.

Results

Sample Distribution

A total of 78 responses were recorded at the end of data collection. Distribution of respondents by professional degree was 37.2% specialists, 62.5% general practitioners and 1.2% other, and by academic role was 19.2% Deans or Assistant/Associate Deans, 43.6% Chair, Director or Section Head of a department and 37.2% Associate/Assistant Professor or Faculty. Multiple responses from a single school were combined for analysis. 51 US schools

out of 66 and 8 Canadian schools out of 10 responded. Response rate was therefore 77.3% and 80% respectively, or 77.6% combined (n=59). (table 20) There were no statistically significant differences between responses from US and Canadian schools. Therefore, results were pooled together for analysis.

Dental Erosion in the Curriculum

Respondents unanimously confirmed inclusion of DE in the didactic curriculum. Many types of departments are involved in teaching DE, including variations of restorative/operative dentistry, preventive dentistry, cariology, oral pathology/medicine/diagnosis, stomatology, general dentistry, comprehensive care, preclinical/clinical sciences, community-based dentistry, biomedical sciences, periodontics, pediatric dentistry, prosthodontics and oral rehabilitation. Thirty-nine percent (n=23) had 1 department involved in teaching DE, 32.2% (n=19) had 2 departments, 23.7% (n=14) had at least 3 departments and the rest answered that there were no departments at their school.

Across all years, DE was taught on average 6.5 hours throughout the entire school curriculum. When fragmented by year, dental students received most of their didactic training on the topic in second year, with an average of 2.3 hours, followed in decreasing order by 1^{st,} 3rd and 4th years with averages of 1.7, 1.6 and 0.9 hour(s) respectively. (figure 4) Some respondents noted that didactic teaching was done through cases, and estimation of hours spent teaching DE was difficult to approximate. Therefore, skewed results may be noted because of overestimation by a very small number of respondents. Hence, number of respondents were calculated for 5 categories: 0, <1, 1, 2 and ≥3 hour(s) for each year. (Figures 5-8) The latter category included answers varying mostly between 3-4 hours, but uncommonly could go as high as 16 hours by a single respondent. Most noticeable results

were that more than half of respondents consistently taught ≤1 hour across all years, with most of the didactic teaching done in 1st and 2nd year. By 4th year, 76% of respondents were not teaching DE.

Indicators and Etiology

Only 15.3% of respondents could identify correctly all the clinical signs of DE. (figure 9) However, considering the question could have been misinterpreted as identifying indicators of erosive tooth wear as a multifactorial process without distinguishing indicators specific to dental erosion, then 64.4% would have identified correctly all clinical signs of erosive tooth wear. Although the correct clinical indicators were the most popular answers, loss of enamel characteristics and dull enamel surfaces was missed by 18.6% of respondents, restorations standing proud by 15.2%, cupping of incisal edges or cusp tips by 10.7% and loss of enamel on the palatal of maxillary anterior teeth by 6.78%. (figure 10) Respondents could also specify any additional clinical signs taught beyond the proposed choices. Some of these responses included enamel loss on the facial surfaces of maxillary anterior teeth and lingual surfaces of mandibular teeth, facial cervical notches, loss of contact with the opposing dentition, TMJ disorders, predominant unilateral loss of enamel, and exposed dentin with a concave surface and a peripheral white enamel line along the marginal gingival tissue.

Various responses were found regarding etiologic factors of DE. (figure 11 and 12) Highest positively identified etiologic agents included both extrinsic and intrinsic sources, specifically different types of acidic beverages (e.g. sodas, fruit juices and sports drinks), GERD and eating disorders. Noteworthy supplementary answers provided by respondents were acidic medications and occupational exposure to industrial acids.

Preventive and Restorative Management

Preventive treatments taught for mild erosion cases were most frequently diet counseling, and hygiene instructions, supporting the concept that behavioral intervention is prioritized. Fluoride therapy is also advocated to increase acid resistance of dental hard tissue. (figure 13) Many respondents added medical referrals for patients suspected of GERD and eating disorders, and specified that dealing with the cause of DE first was more important than treating the symptoms. Baking soda rinse was also suggested to neutralize acid following significant exposure to acid.

Following proper prevention management, when deemed necessary, restorative treatment taught for DE are presented in figure 14. Most frequent comments from respondents were that restorative treatment depends on severity of tooth structure loss, its impact on function and esthetics, and the patients' symptoms.

Tooth Wear Indices

Many tooth wear indices have been suggested in the literature in the past few years, not only for research purposes but also for clinicians to assess and monitor erosive tooth wear. Survey revealed that 18.6% taught ≥2 types of indices, 35.6% taught one, predominantly basic erosive wear examination (BEWE), but mostly, 45.8% of dental schools do not teach any type of tooth wear index. (figure 15)

Diet Analysis

While 12% (n=7) of respondents were unsure, diet analysis is taught by about 85%(n=50) of dental schools. (figure 16) Of those, 66% (n=33) required students to conduct diet analysis at least once throughout their training, 12% (n=6) had no requirements and the remaining respondents were unaware of requirements. (figure 17)

Diet analysis is taught in various departments very similarly to DE teaching, with highest frequency in cariology, preventive and restorative departments.

Competency and Continuing Education

When asked about their opinion on students' competency regarding DE, a vast majority of respondents agreed that most students were able to recognize clinical signs, treat patients adequately and discuss the subject with their patients by the end of their training in dental school. (table 21) Continuing education courses after dental school was deemed very valuable by 37.3% of respondents (n=22), moderately valuable by 45.8% (n=27), slightly valuable by 11.9% (n=7) and finally, not valuable at all by 5.1% (n=3).

Discussion

Although the response rate was fair (77.6%), 17 dental schools failed to respond. Hence, results from this survey was not necessarily representative of all dental schools in the US and Canada. Furthermore, more than half of the respondents listed at least 2 departments involved in the teaching of DE and all parties involved may not have responded. This may lead to incomplete answers. Departments involved varied highly among respondents, and there was an assumption that targeted faculty knew where to redirect survey-link, but communication and awareness of the curriculum among different departments may not be optimal within each school. The topic of DE doesn't seem to be emphasized in a specific core curriculum and department(s) that should be in charge of it remain(s) unclear. It is, at best, part of the cariology curriculum, as shown in European, North American and Latin American studies, but its actual extent is unknown.[127-130] In a European survey of dental schools in 34 countries, 89% included dental erosion within cariology lectures and course units, stating that the interest in this topic has developed significantly over the past 15 years and should therefore be considered an established

subject relevant to cariology.[127] Based on the results of this survey and their subsequent suggested core curriculum for cariology[128], both North American and Latin American studies agreed that cariology core curriculum should encompass erosive and non-erosive tooth wear in addition to dental caries.[129, 130] However, only 64.8% of respondents in Spanish-speaking Latin American dental schools currently included dental erosion as part of cariology education demonstrating a need for educational consensus.[130]

Time dedicated to didactic teaching usually corresponded to ≤1 hour each year, and by the time students reached clinics in 3rd and 4th year, almost no more teaching of dental erosion was done. It is questionable whether students are applying clinically what they have learned the first two years of their training, assuming this training was complete. In fact, only 15.3% of respondents could accurately identify clinical signs of DE. Similarly, in a survey among US dental practitioners, 30.4% correctly identified the signs of DE.[19] In both studies, there were no clinical photographs attached to the survey and perhaps with images, respondents would have been able to identify clinical signs. Only written descriptions were provided. Over 70% of respondents identified signs specific to attrition and normal physiologic wear as dental erosion and difficulty in distinguishing the multifactorial and confluent process of tooth wear may explain this misidentification. Another plausible explanation may be that unlike Europe where erosive tooth wear has been well-accepted and researched, the American perspective on tooth wear is mainly attributed to attrition and abrasion.[18] Regardless, well-established clinical signs of dental erosion such as whipped clay effect, restorations standing proud, cupping of incisal edges and cusp tips, and loss of enamel on the palatal of maxillary anterior teeth were still missed by a few respondents. Although that number may seem low, this translates into a significant number of graduating dental students each year from these schools not receiving proper education on the clinical signs of dental erosion, leading to erroneous diagnosis and improper preventive and restorative management. In Yemen, only 61% of dental practitioners reported learning

about DE in dental school.[124] Furthermore, in a Brazilian survey among dental students, 30% could not report if they had seen patients with dental erosion, 73.1% reported they were not advised by their clinical supervisor to examine their patients for dental erosion and 61.5% did not feel prepared to diagnose the condition.[121]

Most popular etiologies of DE taught included some type of acidic beverage (sodas, fruits juices and sports drinks) and correspondingly, the most popular preventive management strategy was diet counseling. Although 85% of respondents reported teaching diet analysis, much like dental erosion, clinical application of newly learned knowledge is doubtful when only 66% of respondents required at least 1 diet analysis from students during their training. In private practice, it was shown that diet counselling was underutilized by dental practitioners.[19, 125] Diet counselling in private practice is not necessarily given by dentists entirely, but can also be done by hygienists. However, when hygienists from Oregon were surveyed, 60% reported that their dietary counselling skills were not adequately developed during their training and more than half of the respondents provided dietary advice to fewer than 10% of their patients.[122, 123] According to Shah et al., only a little over one third of dental students felt they had received sufficient training in dietary management of patients. Nutritional advice from dental professionals, dieticians and nutritionists is often conflicting, which can negatively impact patients' behavioral modification. This is due to poor nutritional training imparted to dental students and vice versa, oral health training to dietitians and nutritionists. There is definitely a gap to be bridged between professions to provide consistent nutritional guidelines.[131]

As for tooth wear indices taught, the most popular was BEWE. Much like PSR for screening periodontal disease, BEWE is a partial scoring system of the worst tooth surface in each sextant to be used for screening and monitoring erosive tooth wear.[66] It is a simple and reproducible tool, unlike its predecessors. This index was further validated by a recent

study that showed that sextant cumulative score provided a good representation of erosive tooth wear compared to scores of all tooth surfaces.[76] However, 45.8% of respondents did not teach any type of tooth wear index and this may lower dental students' general awareness of dental erosion among their patients. This habit having never been developed, lack of awareness eventually transitions into private practice. In contrast, a survey among Norwegian dental practitioners found that nearly all of them (98.6%) recorded dental erosive lesions in their patients' chart as routine examination. This higher awareness may be the result of integration of the visual erosion dental examination (VEDE) in Norway, a tooth wear index by Espelid and Tveit[74], which has been implemented in both the University of Oslo and the University of Tromsø and recommended for recording dental erosion in the Public Dental Health Service in Norway.[20]

An overwhelming majority of respondents agreed that competence regarding dental erosion of most dental students at the end of their training was adequate. Very similarly, high confidence level was found in survey of US dental practitioners, with over 80% reporting feeling confident diagnosing the condition.[19] Both were unjustified since a very low percentage was actually able to correctly identify clinical signs of dental erosion. Dental educators ought to reassess the manner in which they evaluate assimilation of the topic among dental students, realizing that there is very little application of theoretical notions and utilization of management tools. If education is not imparted in dental school, then continuing education (CE) is of even greater importance, which was acknowledged by most respondents deeming CE moderately to very valuable.

Conclusion

Although the topic of dental erosion is covered in US and Canadian dental school curriculum, whether this topic is emphasized is questionable, but it indubitably has its place

in cariology core curriculum. Tooth wear index and dietary counselling were underutilized in practice and their regular use could potentially raise awareness among dental students, and eventually transition these diagnostic and management tools into private practice. Taught clinical signs of dental erosion still remain unclear. As dental students gain more didactic and clinical knowledge during their training, applying what they have learned is another challenge entirely. Longitudinal learning must be encouraged through repetition, utilization of available tools, and continuing education.

Table 20: Sample Distribution

	N (%)
Total by number of responses	78 (100)
Professional Degree	
Specialist	29 (37.2)
Prosthodontics	*9 (11.5)*
Oral Pathology/Medicine	*9 (11.5)*
Periodontology	*6 (7.7)*
Operative Dentistry	*2 (2.6)*
Public Health	*1 (1.3)*
Unknown	*2 (2.6)*
General Practitioner	48 (62.5)
PhD	1 (1.2)
Role	
Dean or Assistant/Associate Dean	15 (19.2)
Chair/Director/Section Head	34 (43.6)
Associate/Assistant Professor or Faculty	29 (37.2)

	N (%)
Total by number of dental schools	59 (100)
Country	
USA	51 (86.4)
Canada	8 (13.6)

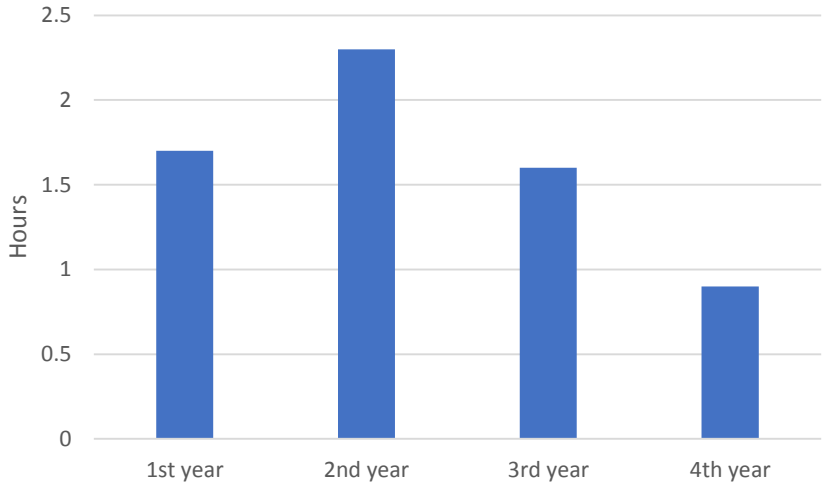

Figure 4: Average Didactic Time Dedicated to Teaching Dental Erosion

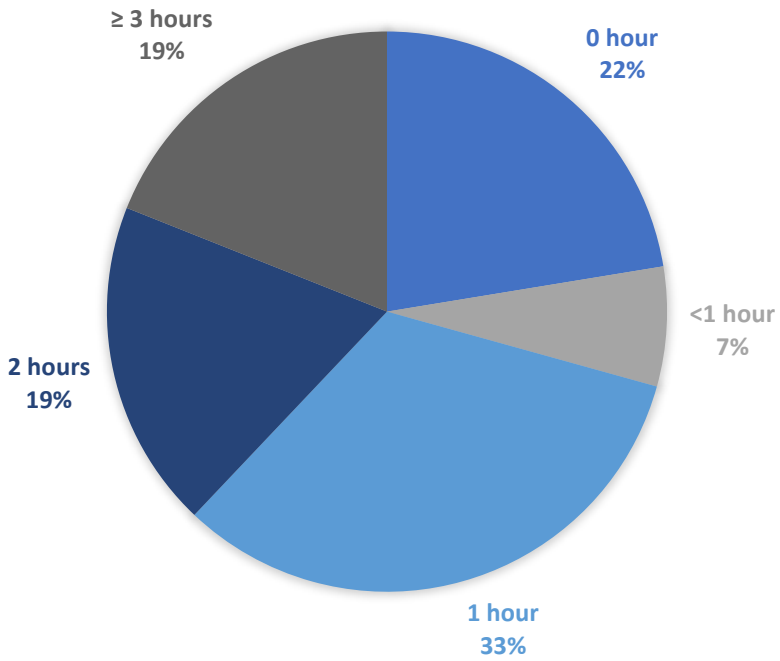

Figure 5: Devoted Time to Teaching DE in 1st Year

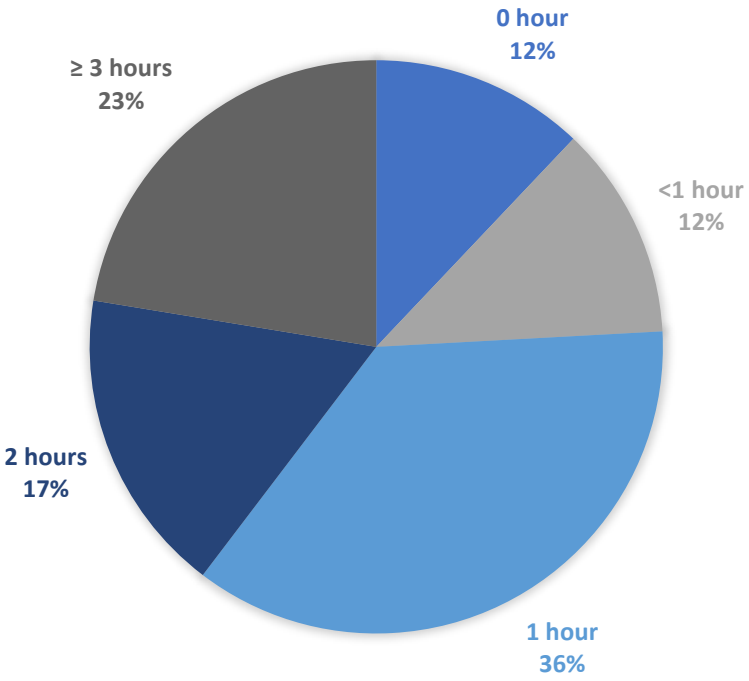

Figure 6: Devoted Time to Teaching DE in 2nd Year

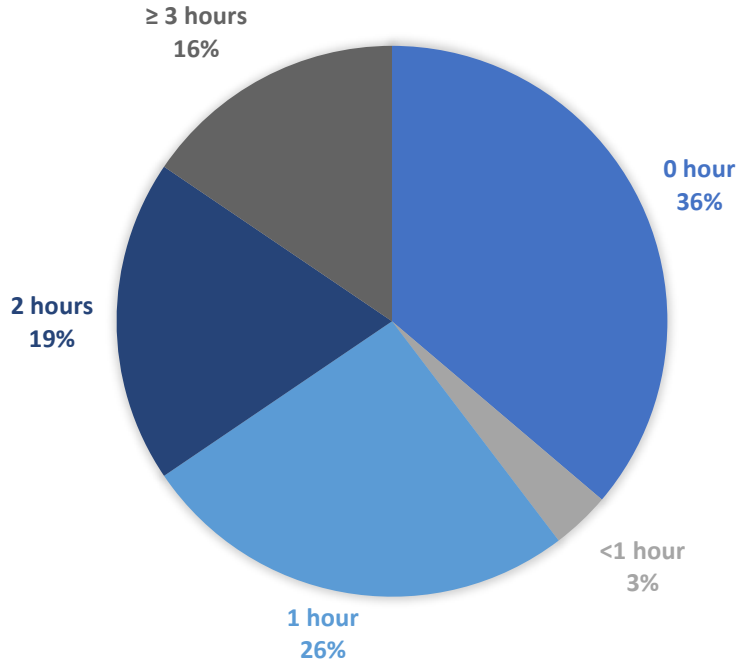

Figure 7: Devoted Time to Teaching DE in 3rd Year

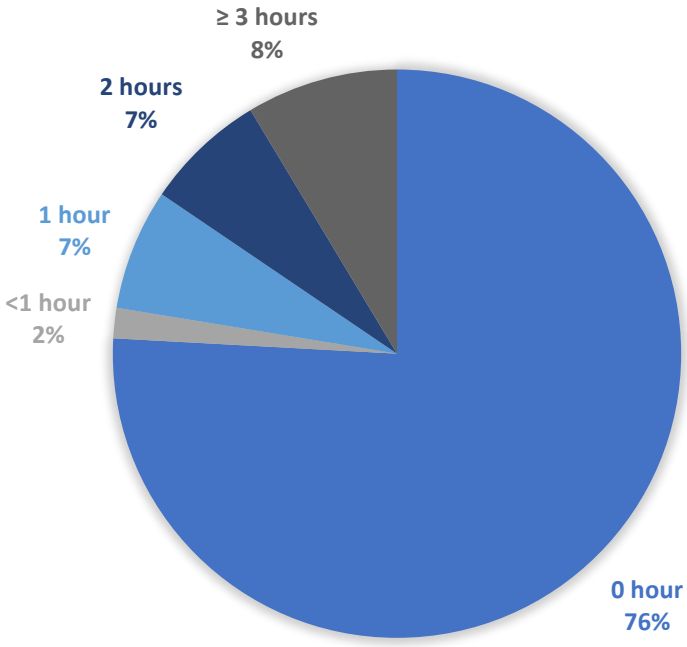

Figure 8: Devoted Time to Teaching DE in 4th Year

Q8 Which indicators are taught in your curriculum for dental erosion?

	Yes	No
Loss of enamel on the palatal surface of maxillary teeth	●	❍
Wear of incisal edges of maxillary anterior teeth	❍	●
Wear of incisal edges of mandibular anterior teeth	❍	●
Restorations appearing higher than the level of the teeth	●	❍
Loss of enamel characteristics, dull enamel surfaces	●	❍
Cupping of incisal edges on incisors or cusp tips on posterior teeth	●	❍

Figure 9: Correct Identification of DE as Respondents Needed to Select

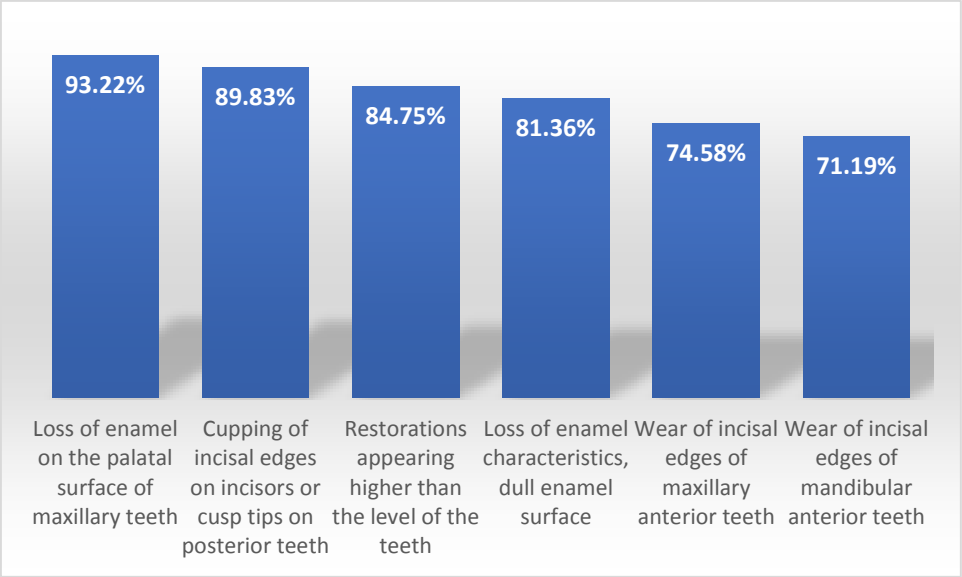

Figure 10: Frequency of Clinical Signs Chosen as Indicators for DE

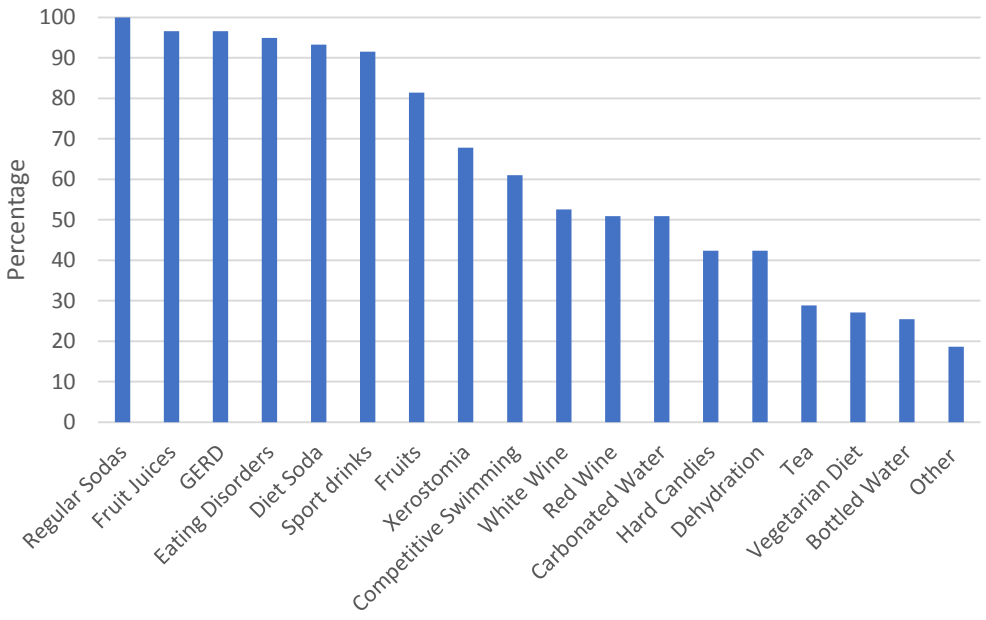

Figure 11: Positive Etiologic Factors Selected by Respondents as Positive Factors

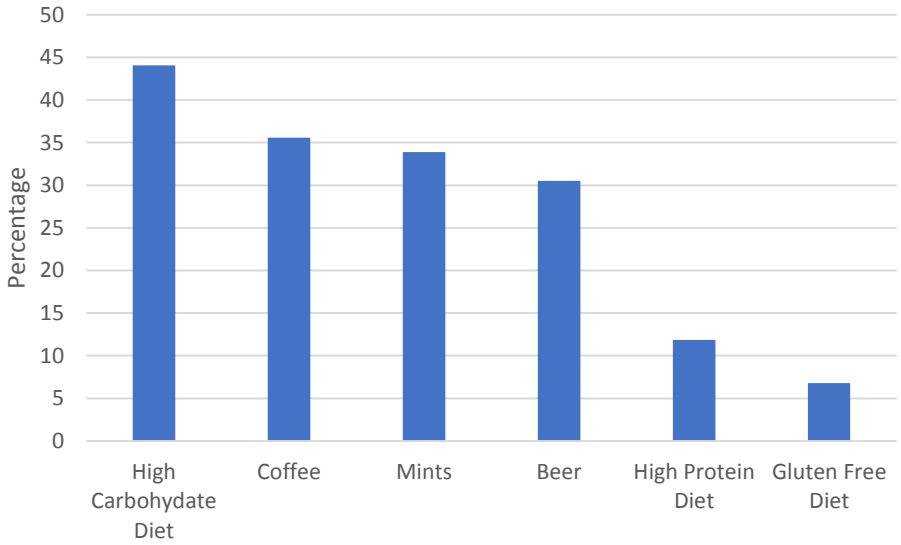

Figure 12: Negative Etiologic Factors Selected by Respondents as Positive Factors

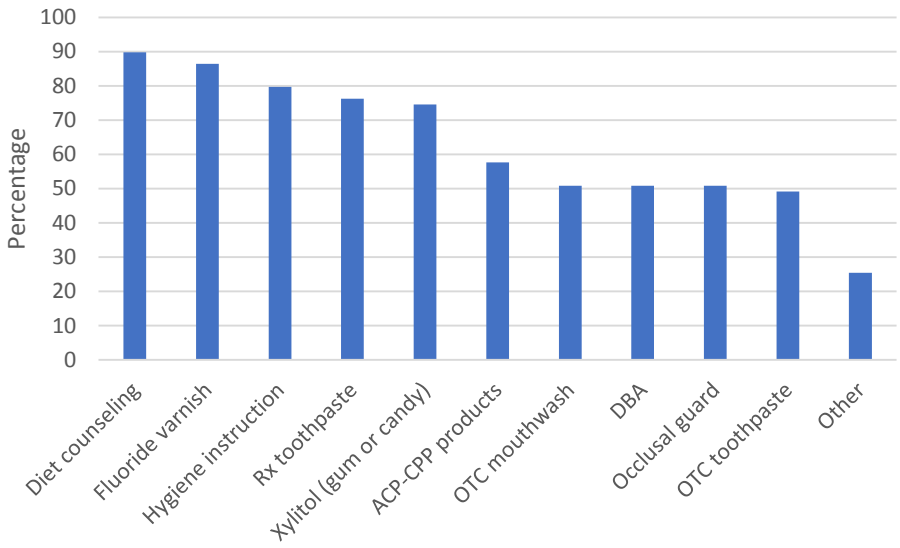

Figure 13: Preventive Measures Taught for Mild DE

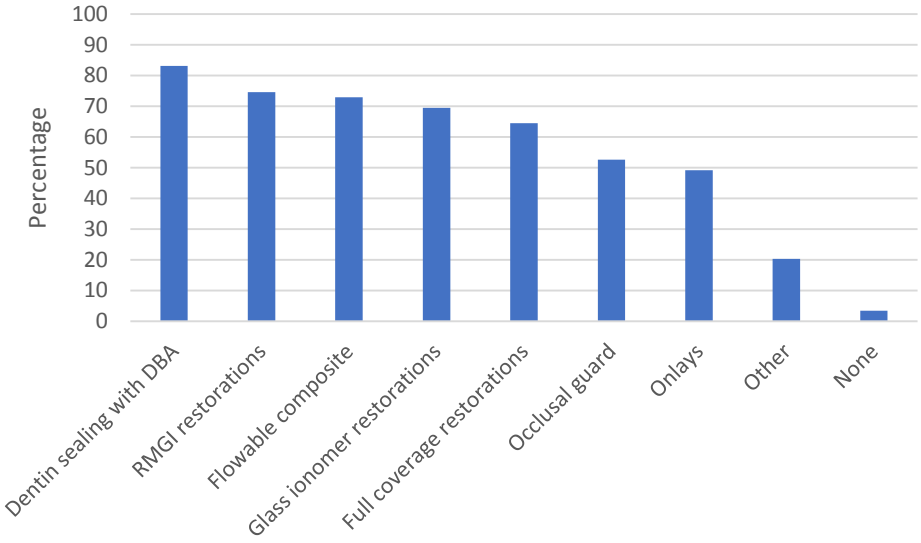

Figure 14: Advocated Restorative Treatments for DE

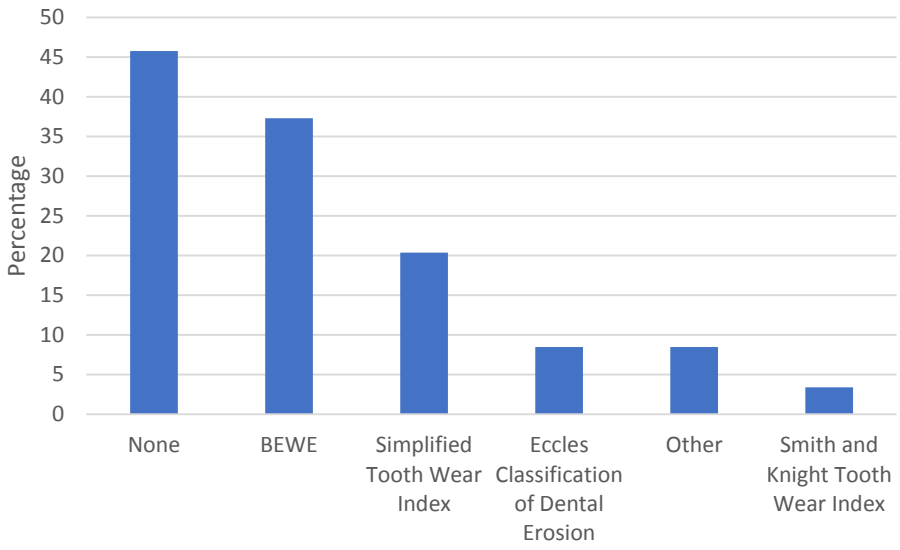

Figure 15: Tooth Wear Indices Taught to Assess and Monitor DE

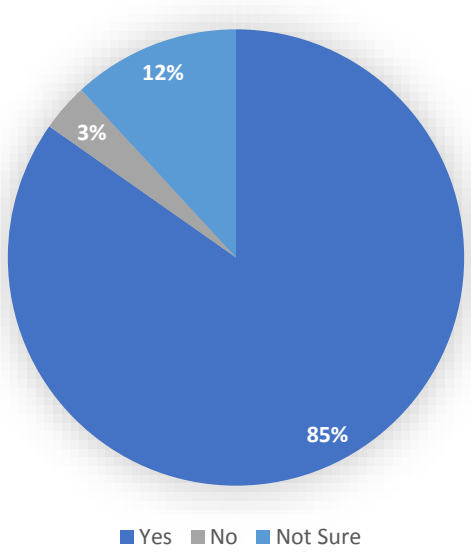

Figure 16: Inclusion of Diet Analysis in the Curriculum

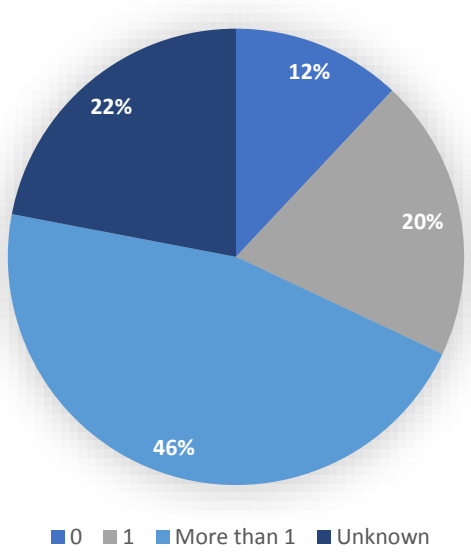

Figure 17: Diet Analysis Requirement

Table 21: Competency Regarding DE After Dental School Training

	Agree N (%)	Disagree N (%)	Unsure N (%)
Recognize the clinical signs of DE	52 (88.1)	1 (1.7)	6 (10.2)
Treat patients whose loss of tooth structure has occurred from DE	47 (79.7)	5 (8.5)	7 (11.8)
Discuss DE process with their patients	55 (93.2)	1 (1.7)	3 (5.1)
Discuss the etiology of DE with their patients	53 (89.8)	1 (1.7)	5 (8.5)

APPENDIX A: DIET DIARY

Department of Operative Dentistry

UNC School of Dentistry at Chapel Hill

4-Day Diet Analysis

Instructions

Please write down everything you ingest (foods, snacks, beverages, medications), and the approximate amount in the appropriate time slot. Please see the next page for an example.

Record this information for 4 consecutive days from Thursday to Sunday.

Please return this completed Diet Analysis to the primary investigator, Dr. Caroline Nguyen Ngoc. A pre-addressed and stamped envelope has been provided for your convenience.

Thursday

TIME	FOOD ITEM	AMOUNT
Breakfast		
Morning		
Lunch		
Afternoon		
Dinner		
Evening		

Friday

TIME	FOOD ITEM	AMOUNT
Breakfast		
Morning		
Lunch		
Afternoon		
Dinner		
Evening		

Saturday

TIME	FOOD ITEM	AMOUNT
Breakfast		
Morning		
Lunch		
Afternoon		
Dinner		
Evening		

Sunday

TIME	FOOD ITEM	AMOUNT
Breakfast		
Morning		
Lunch		
Afternoon		
Dinner		
Evening		

Example

TIME	FOOD ITEM	AMOUNT
Breakfast	Baby aspirin Orange juice Black coffee Toast and jam	1 pill 1 glass 2 cups 2 slices
Morning	Diet coke	12 oz. can
Lunch	Diet coke Cheezies Chocolate cake	12 oz. can Single bag 1 small piece
Afternoon	Water Candies	2 glasses 2 mints
Dinner	Steak Baked potato/butter & sour Cream Cream corn White Wine	12 oz. rib-eye 1 1 helping 1 glass
Evening	Rum & diet coke Popcorn/butter	1 glass 1 microwave pack

APPENDIX B: DENTAL EROSION SURVEY

Thank you for taking the time to complete our survey of dental erosion education in dental schools. This short survey will take about 5-10 minutes to complete.

Q1 What country, state/province, and dental school are you from?

Q2 What is your role in your dental school? (e.g. associate dean for education)

Q3 Which department are you a part of in your dental school?

Q4 Are you a general practitioner or a specialist?

- ❍ General Practitioner
- ❍ Specialist (please specify) _____

Q5 Is dental erosion covered in the didactic curriculum?

- ❍ Yes
- ❍ No

If No Is Selected, Then Skip To The End

Q6 To your knowledge, which department(s) is/are involved with teaching dental erosion?

Q7 Approximately how much didactic time is devoted to the topic of dental erosion?

Hour(s) in 1st year:
Hour(s) in 2nd year:
Hour(s) in 3rd year:
Hour(s) in 4th year:

Q8 Which indicators are taught in your curriculum for dental erosion?

	Yes	No
Loss of enamel on the palatal surface of maxillary teeth	❍	❍
Wear of incisal edges of maxillary anterior teeth	❍	❍
Wear of incisal edges of mandibular anterior teeth	❍	❍
Restorations appearing higher than the level of the teeth	❍	❍
Loss of enamel characteristics, dull enamel surfaces	❍	❍
Cupping of incisal edges on incisors or cusp tips on posterior teeth	❍	❍
Other (please specify):	❍	❍

Q9 Which etiologic factors for dental erosion are taught? (Select ALL that apply)

- ❑ Regular sodas
- ❑ Fruit Juices
- ❑ Sport drinks
- ❑ Bottled water
- ❑ White wine
- ❑ Diet soda
- ❑ Red wine
- ❑ Beer
- ❑ Carbonated water
- ❑ Tea
- ❑ Coffee
- ❑ High carbohydrate diet
- ❑ Vegetarian diet
- ❑ High protein diet
- ❑ Gluten free diet
- ❑ Hard candies
- ❑ Fruits
- ❑ Mints
- ❑ Dehydration
- ❑ Xerostomia
- ❑ Anorexia or Bulimia
- ❑ Gastroesophageal Reflux Disease (GERD)
- ❑ Competitive swimming
- ❑ Other (please specify): _____
- ❑ None of the above

Q10 Which of the following preventive measures are taught to dental students for patients with mild dental erosion? (Select ALL that apply)

- ❑ Xylitol (gum or candy)
- ❑ Fluoride varnish
- ❑ Over the counter toothpaste
- ❑ Prescription fluoride toothpaste
- ❑ Over the counter mouthwash
- ❑ ACP-CPP Products
- ❑ Bonding agents
- ❑ Occlusal guard
- ❑ Hygiene instruction
- ❑ Diet counseling
- ❑ Other (please specify): _____
- ❑ None of the above

Q11 What are the advocated treatments taught to dental students for treatment of dental erosion, when deemed necessary? (Select ALL that apply)

- ❑ Dentin sealing with bonding agents
- ❑ Flowable composite resin restorations
- ❑ Glass ionomer restorations
- ❑ Resin modified glass ionomer restorations
- ❑ Onlays
- ❑ Full coverage restorations
- ❑ Occlusal guard
- ❑ Other (please specify): _____
- ❑ None of the above

Q12 Which of the following wear indices are taught in evaluating dental erosion? (Select ALL that apply)

- ❑ Simplified tooth wear index
- ❑ Smith and Knight tooth wear index
- ❑ Eccles classification of dental erosion
- ❑ Basic Erosive Wear Examination (BEWE)
- ❑ Other (please specify): _____
- ❑ None of the above

Q13 Considering diet is a contributing factor to dental erosion, is diet analysis taught to the dental students?

- ❍ Yes
- ❍ No
- ❍ Not sure

Answer If Considering diet is a contributing factor to dental erosion, is diet analysis taught to the dental students? Yes Is Selected

Q14 To your knowledge, which department(s) is/are involved with teaching dental students how to conduct a diet analysis?

Answer If Considering diet is a contributing factor to dental erosion, is diet analysis taught to the dental students? Yes Is Selected

Q15 How many diet analyses are dental students required to do during their training?

- ❍ 0
- ❍ 1
- ❍ More than 1
- ❍ I don't know

Answer If Is dental erosion covered in the didactic curriculum? Yes Is Selected

Q16 In your opinion, after their training in your dental school, most students are competent to

	Agree	Disagree	Unsure
recognize the clinical signs of dental erosion	❍	❍	❍
treat patients whose loss of tooth structure has occurred from dental erosion	❍	❍	❍
discuss dental erosion process with their patients	❍	❍	❍
discuss the etiology of dental erosion with their patients	❍	❍	❍

Q17 In your opinion, how valuable are continuing education courses on dental erosion after dental school?

- ❍ Not at all
- ❍ Slightly valuable
- ❍ Moderately valuable
- ❍ Very valuable

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